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T R E A T I S E
Containing the
E L E M E N T A R Y P A R T
O F
F O R T I F I C A T I O N ,
R E G U L A R A N D I R R E G U L A R .

W I T H
R E M A R K S on the Constructions of the most
celebrated Authors, particularly of Marshal de VAUBAN
and Baron COEHORN, in which the Perfection and
Imperfection of their several Works are considered.

For the U S E of the
Royal Academy of A R T I L L E R Y at Woolwich.

Illustrated with Thirty-Four Copper Plates.

The T H I R D E D I T I O N .

By J O H N M U L L E R ,
Professor of A R T I L L E R Y and F O R T I F I C A T I O N .

L O N D O N ,
Printed for J. NOURSE, Bookseller to His MAJESTY.
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To his GRACE

J O H N

Duke of MONTAGU, &c.

*One of his Majesty's most honourable
Privy-council, Great Master of the
most honourable Order of the Bath,
Knight of the most noble Order of
the Garter, Master of the King's
great Wardrobe, Colonel of the
Queen's royal Regiment of Horse,
and Master-general of the Ord-
nance, &c.*

May it please your Grace,

THE institution of the royal
academy for the instruction of
military gentlemen, will be a lasting
monument of your Grace's attention
to his Majesty's service, and of your
encouragement of useful learning.

A 2

As

DEDICATION.

As your Grace has been pleased to appoint me to instruct the young gentlemen of the academy, and this work having been compiled for their improvement, it naturally claims your Grace's patronage ; which, if I am so happy to obtain, will gratify the utmost of my wishes, as I have thereby an opportunity of assuring your Grace of the sense I have of your goodness and generosity, and of the gratitude with which I am most respectfully,

Your Grace's

most obedient

and most devoted

humble servant,

From the Royal Academy at
Woolwich, August 27th, 1746.

John Muller.

T H E
P R E F A C E.

SINCE the invention of gunpowder, fortification has received various improvements, and many have been the books wrote upon this subject, which might incline one to think, that it was arrived to its utmost perfection ; but upon an impartial survey of most of the writers, it will be found, if I mistake not, that many of them are deficient either in theory or practice, and others blinded by prejudice, so that there is much room left to exercise the genius and excite the industry of those whose business leads them to this study ; besides, as the art of attacking received several improvements in the late wars, it should follow that the art of fortifying requires likewise improvements in proportion.

Not a few authors have proceeded upon maxims, some of which are uncertain, others trifling, and they have often neglected those which are self-evident ; this together with their adopting some favourite scheme has retarded its progress.

Particular care should be taken, in tracing plans on paper, in order to know whether

they are practicable or not; which has been neglected by many even by some of those who are generally esteemed the best writers.

Some think it sufficient, that they make schemes with a great many outworks upon outworks, so as these works defend each other; without considering whether the town thus surrounded is spacious enough to hold, besides the inhabitants, a garrison sufficient to defend it; or the expence it would require to maintain them, and likewise the necessary stores: it is true they never fail to tell you that they have some secret, which enables them to build for half the cost that others do.

Notwithstanding the art of fortifying irregular places is most useful, yet no author, whom I know, has given the least hint or direction whereby to judge of the advantage or disadvantage of the several parts of such a place: all they have done consists in giving some schemes of their own fancy, and telling us no work ought to be made without being defended by some other; not considering that although the parts defend each other, there may be some which are much stronger than others.

For the true art consists in making an irregular fortification every where equally strong,
which

which they seemed to be ignorant of, or if they knew it, they could not distinguish the strong from the weak.

The commentators on M. *Vauban's* methods, who are so lavish in his praises, do not mention any thing of his way of fortifying irregular places; although he understood it better than any one, as appears by a great many examples of this kind; neither has any of them shewn why he made always the exterior side next to a river much longer than any other, as may be seen in the plans of *Hunningen*, and *Sarrelouis*; yet it is unquestionable that a man of so much experience had some very good reasons for what he did.

The very same mistake is made with regard to M. *Coeborn*, by those who praise him to the skies, on account of his treatise which he published before he had acquired so that great experience, for which he was justly esteemed in his latter years; and it is an undoubted proof that he himself was of the same opinion afterwards, since he did not use any of the methods published in his book when he fortified *Bergen-op-Zoom* and part of *Manheim*: had he left us in writing that knowledge which he acquired by his great experience. it would have undoubtedly been

worthy of so great a man, and would have perfectly justified the high opinion the world conceived of him.

It will not be improper to mention *Daniel Specke*, who published a book of fortification in the year 1589 at *Strasbourg* in the *German* language, which *M. Coeborn* has chiefly followed, as may be seen by comparing their works; and *Dilichius*, who published his *Peribologia* in the year 1640, at *Frankfurt on the Main*, in *German* and *Latin* was followed by *M. Vauban*; since there is nothing in this author, besides his concave flanks, but what is to be found in the other.

These two *German* authors were undoubtedly the best in their times, and as it were the fountains from which the present methods are derived: the few improvements made since are sufficient proofs of their skill, and at the same time of the barrenness of invention of those since.

As *M. Vauban's* methods are now most in vogue, and chiefly used all over *Europe*; we thought it would not be improper to explain them first, and after his, those of *M. Coeborn*, which are next in esteem; and then lay down some principles, whereby the advantage or disadvantage of a fortification may

be known ; after this, we have examined their methods in each part separately, and pointed out their several deficiencies, and afterwards have given some of the same works with proper corrections.

Then we propose three different methods which we hope are not altogether to be despised, and which we think might be used according to the different situations and importance of places: this with the constructions of some of the most celebrated authors and their examination, finishes the regular part of fortification.

We begin the irregular, by shewing how a place, that cannot be made regular, may be made so, as one half may be similar and equal to the other half ; then we enquire which part of such a fortification is strongest and which is weakest ; these principles, which are demonstrable, serve to judge of the weakest and strongest part of any irregular fortification whatsoever ; and for a farther confirmation of the truth of them, we refer the reader to several places in *Flanders* fortified by the greatest masters, and which agree exactly with what we have advanced.

As the greatest strength of this, and all maritime nations, consists in traffic, and as fortified

fied places which lie near rivers, lakes, creeks, or the sea, chiefly serve to protect and promote trade, we have dwelled upon and explained their constructions in a more particular manner, and nothing has been omitted that could be thought of, which might any ways contribute to the right understanding this subject.

Several examples are given, in order to shew, how and in what manner the reader may proceed, if he finds himself employed in the construction of such places ; the several advantages and disadvantages of their situations are carefully examined, and those which require least expence to fortify, and are most convenient in other respects, are distinguished ; for a further explanation we have examined several sea-port towns, and pointed out those which deserve to be imitated, and others, which should be avoided ; the plan of *Toulon* with its harbour is inserted, as being one of the best in *Europe* : lastly, we have given the principal conditions required in the construction of such places. Having thus far explained the several parts of irregular fortification, we proceed to shew how citadels are to be joined to places, and the faults committed in some of the finest in *Europe* are pointed out ; the work concludes with
the

P R E F A C E.

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the manner of building forts, where particular notice has been taken of the methods generally followed in the building of such works, near rivers and the sea, and shewn their ill consequences : as this subject is very important to this nation, on account of the many forts we have and daily build, so we have endeavoured to point out the most proper manner, in which they should be made.

The present undertaking contains the theoretical part of fortification only, that which relates to the practice has been treated in another volume, so that the whole together makes a complete treatise of fortification, containing all the most material principles necessary to an *English* engineer. I may venture to say, that whoever reads it with proper attention, will find no endeavours have been wanting to explain every thing that is necessary in as short a compass as was possible.

In this edition, particular care has been taken to enlarge the explanations of the constructions and remarks wherever it was thought necessary, in order to set every thing in as clear a light as we could : for nothing else seemed to be wanting to complete the work.

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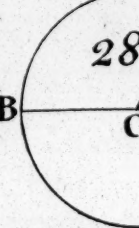
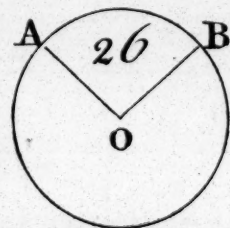
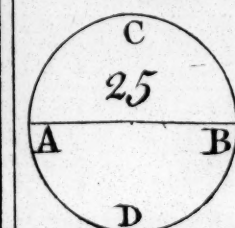
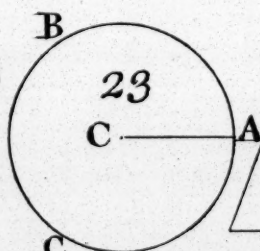
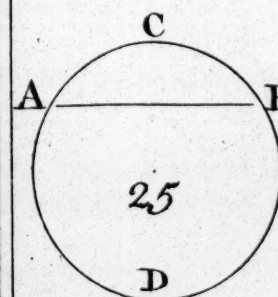
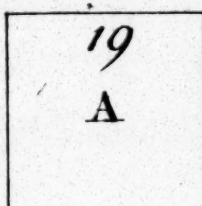
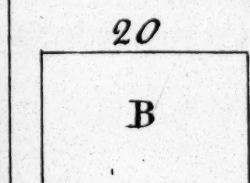
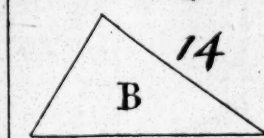
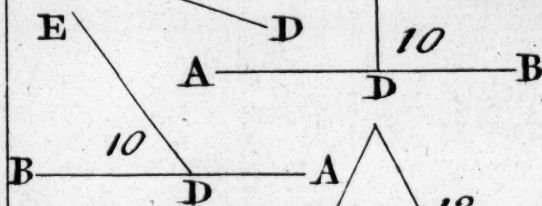
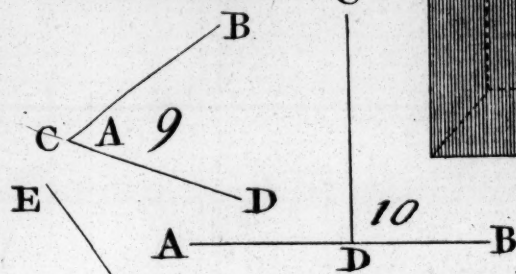
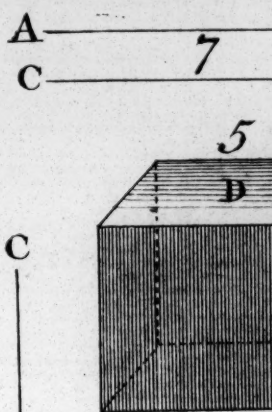
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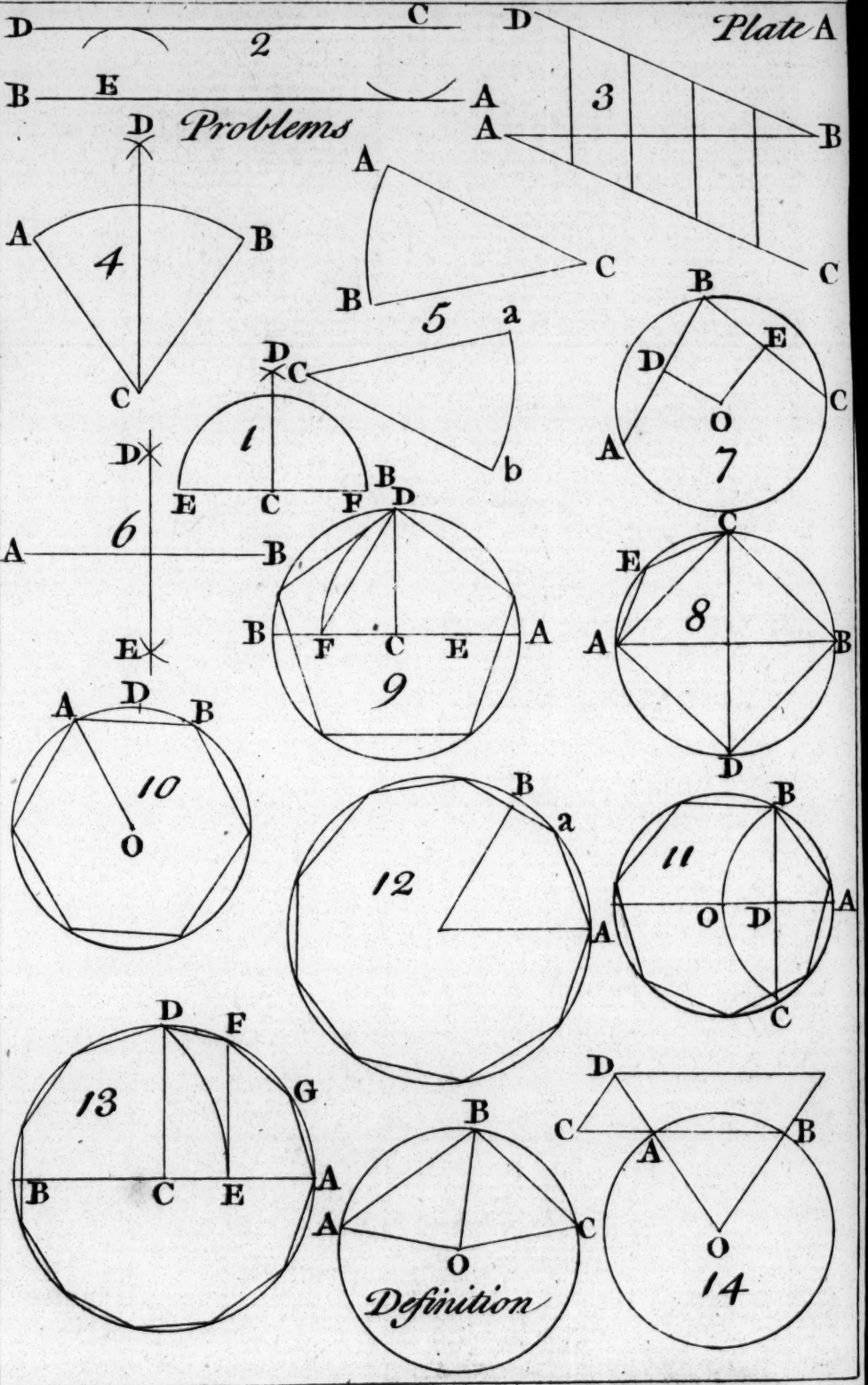
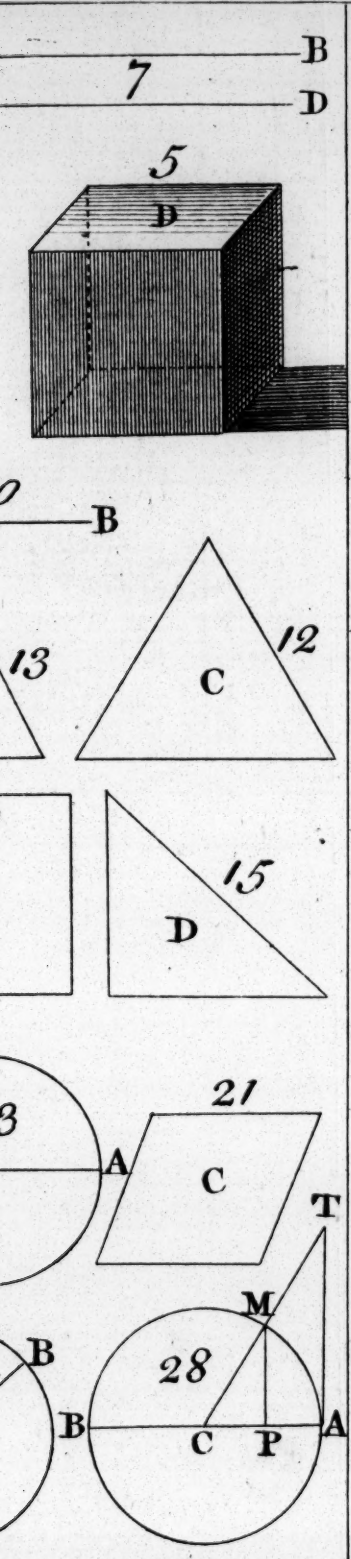
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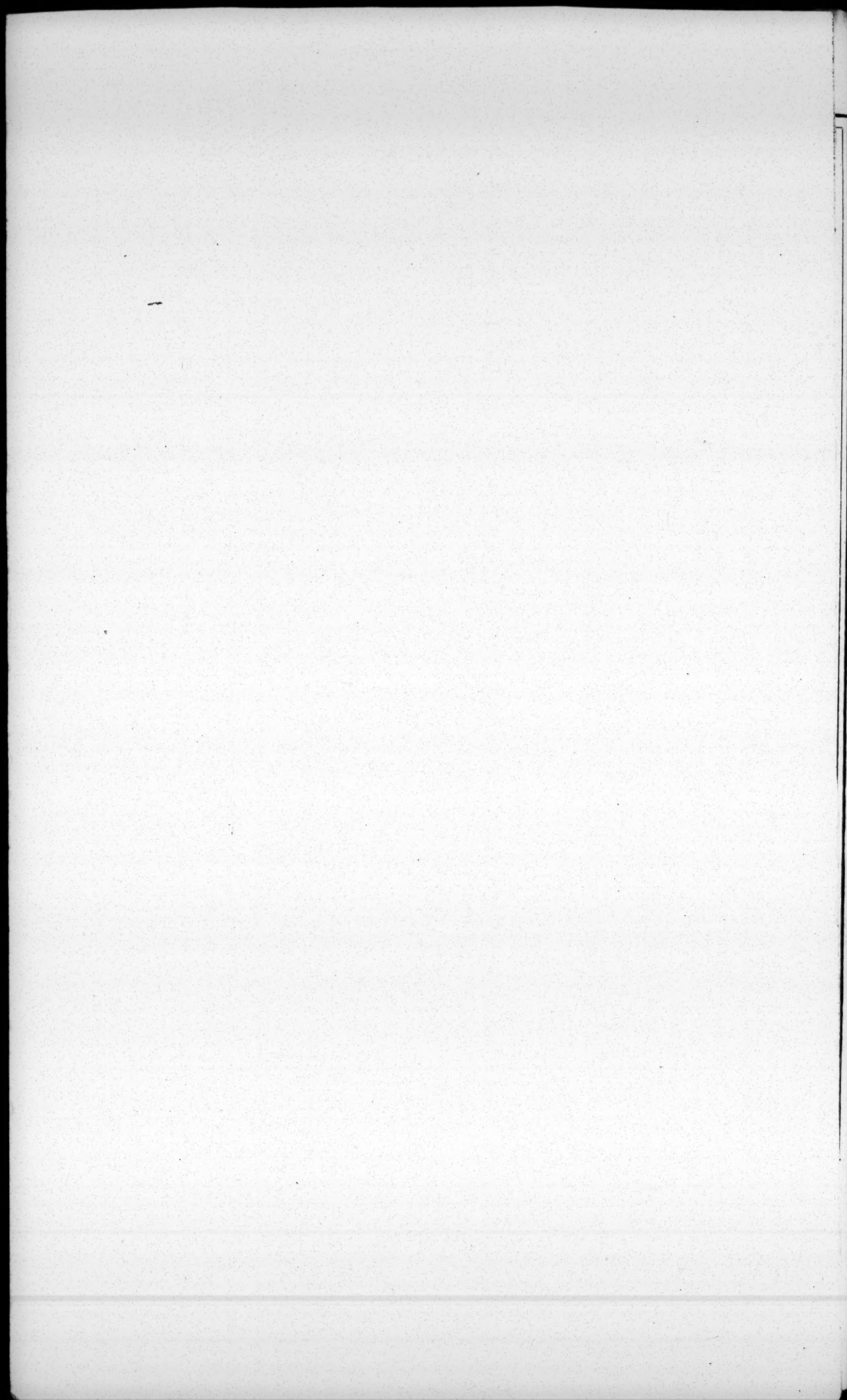
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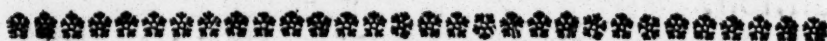
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CONTAINING
The Elementary P A R T
O F
F O R T I F I C A T I O N.



S E C T. I.
Of practical Geometry.

D E F I N I T I O N S.

1. **E**XTENSION is distinguished Plate A.
into *length*, *breadth*, and *thickness*,
which are called *dimensions*.

2. A *line* has only length, as AB.

3. The terms or bounds of a line are called
points, and have no dimensions.

4. A *surface* has length and breadth only,
as C.

The bounds of a surface are lines.

B

5. A

5. A *solid* has length, breadth, and thickness, as D.

The bounds of a solid are surfaces.

6. A *right-line* is the shortest that can be drawn from one point to another.

7. *Parallel lines* are those which are everywhere equidistant, although produced *ad infinitum*, as AB, CD.

8. A *plane surface* is that which lies evenly between its bounds, and agrees with a right line placed on it according to any position.

9. The opening of two lines, which meet each other in a point, is called an *angle*, as A.

N. B. An angle is generally expressed by three letters, as ABC, with the letter expressing the angular point in the middle.

10. If a line CD meets another line AB, so that the angles CDA, CDB, are equal; that line CD, is said to be *perpendicular* to the other AB.

And the equal angles CDA, CDB, are called *right angles*.

But if the line is oblique, as DE, the greatest angle EDA, is called an *obtuse* angle; and the least EDB, an *acute* angle.

OF FORTIFICATION.

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11. A plane surface terminated by three right lines, is called a *plane triangle*.

12. When the three sides of a triangle are equal, it is called an *equilateral triangle*, as C.

13. When only two sides are equal, an *isosceles triangle*, as A.

14. When the three sides are unequal, a *scalene triangle*, as B.

15. When one angle of a triangle is a right angle, it is called a *right-angled triangle*, as D.

16. Any one side of a triangle may be called the *base*, and the angular point opposite to the base, is called the *vertex*.

17. In a right-angled triangle, the side opposite to the right angle is called the *hypotenuse*.

18. A plane of four sides, is called in general a *quadrilateral figure*.

19. A quadrilateral, whose four sides are equal as well as the four angles, is called a *square*, as A.

20. If the four angles are equal, and only the opposite sides a *rectangle*, as B.

21. If the opposite angles are only equal, and the opposite sides a *parallelogram*, as C.

22. A plane figure of above four sides, is called in general a *polygon*.

B 2

23. A

THE ELEMENTS

23. A *circle* is a plane figure bounded by one continued line ABC called the *circumference*, which is every where equally distant from a point O within the circle, called the *center*.

24. Any line, as AO, drawn from the center to the circumference, is called a *radius*.

25. Any line, as AB, terminating in a circle, is called a *chord*, which divides the circle into two parts, ABC, ADB, called *segments*; the parts of the circumference, terminated by the chord, are called *arcs*, and when the chord passes through the center, it is called a *diameter*, and divides the circle into two equal parts, called *semicircles*.

26. Any part of the circle, as AOB, terminated by two radii and an arc, is called a *sector*.

27. The measure of an angle is the arc described from the angular point as center with any radius, and terminated by the lines which form the angle.

28. A line AT, which touches a circle in one point A only, is called a *tangent*; and the point A, where it touches, the point of *contact*.

29. The line CT drawn from the center and terminated by the tangent, is called the *secant*

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secant of the arc AM, as AT is called its *tangent*, and the perpendicular PM to the radius CA the *sine*, CP the *cosine*, and AP the *versed sine* of that arc, or of the arc BM, its supplement to a semi-circle.

30. A polygon is called *regular*, when all its sides are equal as well as all its angles; and *irregular*, when they are unequal.

31. A polygon is said to be *inscribed* in a circle, when all its angles touch the circumference; and *circumscribed* about a circle, when all its sides touch the circle.

Polygons are distinguished by the number of their sides, viz.

5	Pentagon.	9	Enneagon.
6	Exagon.	10	Decagon.
7	Eptagon.	11	Ondecagon.
8	Octagon.	12	Dodecagon.

Problems useful in Fortification.

1. To draw a line, through a given point C, perpendicular to another line AB.

From the given point C as center, describe an arc with any radius so as to meet the line AB, in two points E, F, and from these points as centers, describe two arcs with the same

B 3

radius,

radius, so as to intersect each other at D; then the line drawn through this intersection and the given point C will be the perpendicular required.

2. *To draw a line, through a given point C, parallel to another line AB.*

From the given point C as center, describe an arc so as to touch the line AB, and from any point E in AB as center, describe another arc with the same radius; then the line drawn through the given point C, so as to touch this arc, will be the parallel required.

3. *To divide a given line AB, into any number of equal parts, as five.*

Through the extremity A draw a line AC at pleasure so as to make any angle with AB, and through the other extremity B, draw BD parallel to AC: then if from the point A towards C, there be set off as many equal parts less one of any length, on AC, as the line AB is to be divided into, and the same thing to be done on the line BD; the lines which join the opposite points will divide the line AB into the desired number of equal parts.

4. *To divide a given angle ACB into two equal parts.*

From

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From the angular point C as center, describe an arc with any radius, meeting the legs of the angle at A, B: from these points as centers, describe two arcs with the same radius, so as to intersect each other at D; then the line drawn through this intersection and the angular point C, will bisect the given angle.

5. *To draw a line CA, so as to make an angle ACB, with a given line CB, equal to a given angle a c b.*

From the points C, c, as centers, describe two arcs with the same radius taken at pleasure: make the arc AB equal to the arc a b; and the line drawn through the points C, A, will make the angle required.

N. B. Mathematicians suppose the circumference of a circle to be divided into 360 equal parts called degrees, each degree divided into 60 equal parts called minutes, as likewise each minute into 60 equal parts called seconds.

These divisions are generally marked on a brass semi-circle or a rectangular piece of ivory, called protractor, and serve either to measure any angle by, or to lay down any angle on paper.

Hence a quadrant or the measures of a right angle is 90 degrees, as being the fourth

B 4

part

part of the circumference ; a semi-circle or the measure of two right angles 180 ; and because the three angles of a triangle being equal to two right ones, each of the angles of an equilateral triangle, is one third of 180 ; that is, 60 degrees, or the sixth part of the whole circumference.

6. *To bisect a line AB, by a perpendicular to it.*

From the extremities A, B, as centers, describe arcs on both sides of that line, with any radius so as to intersect each other at D, and E ; then the line DE will be perpendicular to and bisect AB.

7. *To describe the circumference of a circle, through three given points A, B, C.*

Join these points by two lines AB, BC ; bisect these lines by the perpendiculars DO, EO ; then their intersection O, will be the center of the circle desired.

8. *To inscribe a square in a circle.*

Draw the diameter AB, to which draw the diameter CD perpendicular ; then the lines joining the extremities of these diameters will be the square ABCD required.

If the quadrant AC be bisected in E, the chord AE or EC will be the side of an octagon, inscribed in the circle.

9. *To*

9. *To inscribe a pentagon or a decagon in a circle.*

Draw the radius DC at right angles to the diameter AB, bisect AC in E, and from the point E as center, describe an arc through the point D meeting the diameter AB in F, draw DF; then will DF be the side of the pentagon, and CF that of the decagon inscribed in the circle.

10. *To inscribe an exagon in a circle.*

Take the radius AO and carry it round the circumference, and you will have the exagon required.

If the arc AB be bisected at D, the chord of the arc AD or DB, will be the side of a dodecagon inscribed in the circle.

N. B. The eptagon, enneagon, and ondecagon, cannot be geometrically inscribed in a circle; for which reason we shall give mechanical constructions of them, which are sufficiently exact for practice.

11. *To inscribe an eptagon in a circle.*

From any point A in the circumference as center, describe an arc through the center O, meeting the circumference in B and C; draw CB and the radius AO; then the half BD or DC of BC will be the side of an eptagon nearly.

12. *To*

THE ELEMENTS

12. *To inscribe an enneagon in a circle.*

Carry the radius from A to B, and divide the arc AB into three equal parts, by repeated trials; and let A a be two thirds of AB; then the chord A a will be the side of the enneagon exactly, if A a is exactly two thirds of AB.

13. *To inscribe an ondecagon in a circle.*

Draw the radius CD, perpendicular to the diameter AB; from the extremity B as center, describe an arc through the point D, meeting the diameter in E, at E erect a perpendicular EF, to the diameter, or draw EF parallel to CD, meeting the circumference in F: then if the arc A F be bisected in G, the chord of AG or GF will be the side of the ondecagon required.

14. *To inscribe a polygon in a circle, so that its sides shall be of a given length.*

Inscribe a similar polygon, that is, one of the same number of sides, in any circle by the foregoing problems; and let AB be one of those sides, which produce to C so as BC be equal to the given side, and draw CD parallel to the radius OB, till it meets the radius OA produced at D; then OD will be the radius of the circle required.

This

OF FORTIFICATION.

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This problem is easier solved by means of a sector, in this manner. On the inner edge is a line marked polygon, whose numbers answer from a square or pentagon to a dodecagon ; you take the length of the side of the polygon which is to be inscribed in a circle, between the points of your compass; and set one point upon the number of the sides on the sector, and open the sector so as the other point of the compass meets the same number on the other leg of the sector ; then keeping the sector thus open, you take the opening from 6 to 6 on the sector between the points of your compass, and that will be the radius of the circle wanted.

DEFINITIONS.

The angle ABC made by any two contiguous sides of a polygon is called the *angle of the polygon* ; and the angle AOB made by two radii drawn to the extremities of the same side of a polygon, is called the *angle of the center*.

The angle of the center of a regular polygon is found, by dividing 360 degrees by the number of the sides : thus 360 divided by 5 gives 72 degrees for the angle of the
center

THE ELEMENTS

center of a pentagon ; and 360 divided by 6 gives 60 degrees for the angle of the center of an exagon.

But the angle of the polygon is found by subtracting the angle of the center from 180 degrees ; thus $180 - 72 = 108$ degrees in the pentagon ; and $180 - 60 = 120$ degrees in the exagon.

Polygon.	Ang. Cent.	Ang. Polyg.
5	72	108
6	60	120
7	$51\frac{3}{7}$	$128\frac{4}{7}$
8	45	135
9	40	140
10	36	144
11	$32\frac{8}{11}$	$147\frac{3}{11}$
12	30	150

Of

*Of the measures and scales used in
Fortification.*

The *French* make use of a measure called a *toise*, which is six feet, and therefore, is what we call a *fathom* here in *England*.

The *Dutch*, and most of the *Germans* make use of the *Rhinland rod*, which is 12 *Rhinland feet*.

The *French* royal foot is to the *English* foot, as 114 to 107, or as 16 to 15 nearly, in smaller numbers.

The *Rhinland* foot is to the *French* foot, as 1033 to 1068, or as 29 to 30 nearly, in smaller numbers; and therefore, half the *Rhinland rod* is to a *French toise*, as 29 to 30 nearly.

As we propose to give *M. Vauban's* constructions, with those of the most celebrated authors of that nation, we shall use the word *toises* in this work, as being more convenient for understanding their methods than that of *fathom*; the valuation of the *French* into *English* measure, may be easily made by the proportion given above.

When a plan of a fortification is to be drawn, which is to be executed, it will be
con-

convenient to have a scale divided into equal parts; as for example, an inch divided into 20, 25, 30, 35, 40, 45, 50, 55, 60: then that of 40 to an inch is to be used in this case, in order to express every part distinctly, which cannot so well be done upon a smaller one.

When a plan is to be drawn upon any other occasion, any other scale will do, which may be greater or less, according as it is thought most convenient.

The profiles are generally drawn upon a scale of thirty feet to an inch; because they are to express the heights of the different parts, which cannot so well be done upon a lesser.

If a scale ready divided cannot be had, or such a one as may be wanted upon a particular occasion, there must be one made on strong paper, by the help of the third problem.

Colours used in the drawings of Fortifications.

It is necessary to use colours in the drawings of plans and profiles of a fortification, in order to distinguish every particular part, and separate, as it were, the one from the other,

so

so as to make their difference more sensible. The manner of using colours, is called *colouring*.

The first and most necessary thing required in drawing, is *Indian ink*; for it serves, in drawing the lines, to express hills or rising grounds, and in short, for all what is called shading in drawings.

There are six different sorts of colours, generally used in these kinds of drawings, viz. *carmine*, *verdegrease*, *sap-green*, *gum-bouch*, *indigo*, and *umber*.

The best sort of Indian ink is of a bluish black, soft, and easily reduced into a liquid, free from sand or gravel: it is sold in sticks from three pence a stick to half a crown, according to its goodness and quantity.

The manner of liquefying it is by putting a little clear water into a shell or tea-cup, and rubbing it gently till the water is black, and of a consistence much like common ink; when it is used for drawing lines, it must be made very black, though not too thick, otherwise it will not easily flow out of the drawing pen: but when it is for shading, it must be pale, so as to go over the same shade several times, which will make it look much finer and softer than if it was done at once.

Carmine

Carminé is in powder, and the finest red we know of; it serves for colouring the sections of masonry, the plans of houses, and other buildings; as likewise their elevations, but is then made of a paler colour.

This colour is also used for drawing red lines in plans, to represent walls: it is very dear, being generally a guinea an ounce, but a little goes a great way.

The verdegreafe used in drawings, which is commonly called *sea-green*, is liquid, and sold in little vials for six pence a-piece; it serves to colour wet ditches, rivers, seas, and in general to represent all watry places.

Sap-green is in stone, of a yellowish green, when liquefied with clear water; but when it is mixt with some sea-green, it makes a fine grass-green; as all mixt colours are liable to fade, if *verd'iris* can be had, it will be much better; sap-green is very cheap, for two or three pence, one may have as much as will serve a great while.

Gum-bouch is a fine yellow in stones, and very cheap; it serves to colour all projects of works; as likewise to distinguish the works unfinished from those that are so. It serves also to colour the trenches of an attack.

This

OF FORTIFICATION.

17

This colour is prepared, by taking water in a hair pencil, and rubbing it gently, then putting it in a shell, and this is repeated till the colour is as strong as is necessary.

Indigo is in small cakes, and very cheap; it serves to colour iron and roofs of buildings, which are covered with slates: it must be well ground upon a smooth stone or glass, and then mixt with a little gum-water.

If the sea-green is too pale, by mixing a little indigo with it, it will make a fine bluish colour.

Umber is a yellowish brown colour in powder; when it is mixt with gum-water, it serves to colour dry ditches, sand, and all things of earth. By mixing a little red ink with it, it will also make a wood colour. If some tobacco leaves are steeped in clear water for some hours, and filtered through a woollen cloth, or brown paper, with a little red ink mixt in it, it makes the best earth or wood colours, as lying smoother than any other.

In drawing encampments, it is necessary to have a fine blue, to represent the colour of blue cloth; *smalt*, sold in shells for about a groat a-piece, is very good for that purpose, or else *Prussian blue*, well ground and mixt with a little gum-water.

C

Gum-

Gum-water is best when it is made some time before it is used; for which reason, take some gum-arabic, and steep it in clear water for some hours till it is dissolved; then strain it through a woollen cloth or brown paper, and preserve it in a vial, well stopped, that no dirt can come into it, till it is wanted.

SECTION II.

Of regular Fortification.

Fortification, is the art of inclosing towns with works in such a manner, as that a small number of men may resist, for some time, a considerable army.

The attack of a place, is the art of making and conducting all the different works in a siege, in order to become master of the place.

And the defence of a place, is the art of defending a town besieged, with all the advantages that the fortification will admit of.

The art of fortification may be distinguished into two parts, *viz.* the elementary or theoretical, and practical.

The

The elementary part consists in teaching the plans and profiles of a fortification on paper, with scales and compasses ; and to examine the systems proposed by different authors, in order to discover their advantages and disadvantages.

And the practical part consists in forming a project of a fortification, according to the nature of the ground and other necessary circumstances, to trace it on the ground, and to execute the project, together with all the military buildings, such as magazines, store-houses, bridges, &c.

It is the elementary part which we propose to treat of in this work, reserving the other for a second volume, which we shall divide into regular and irregular fortification ; but before we enter any farther upon the subject, it will not be disagreeable to beginners to say something concerning the rise and progress of fortification.

The origin and rise of fortification is undoubtedly owing to the degeneracy of mankind ; for in the first ages of the world, men were dispersed up and down the countries in separate families, as we are told in the histories of the Jews and Scythians, who wandered from one place to another for the sake of find-

ing pasture for their cattle. These families became in time so numerous as to form large communities, which settled all together in a place; from whence villages and towns had their origin and rise: but they found it was necessary, for the common security, to surround those towns with walls and ditches, to prevent all violences, *and sudden surprizes from their neighbours*. This was sufficient for some time, till offensive weapons were invented, and conquering became a fashion; then walls with loop-holes were made at proper distances, in order to screen the defenders against the arrows of the assailants; but finding that as soon as the enemy got once close to the walls, they could from no part be discovered or repulsed; for this reason they added square towers at proper distances from each other, so that every part of the wall might be defended by the adjacent sides of the towers. However, this manner of inclosing of towns was found to be imperfect, because there remained still one of the faces of the towers which fronted the field that could not be seen from any other part, and therefore could not be defended. To remedy this, they made the towers round instead of square, imagining this figure to be the strongest to resist the

the battering engines, as likewise to be better defended from the other parts of the wall.

Notwithstanding the superiority of this method above the former, there remained yet a part of these towers unseen and incapable to be defended; which made them change the figure of the towers again; that is, they made them squares as before; but instead of presenting a face to the field as formerly, they presented an angle; by this means they effectually found out such a disposition of their works, that no part could be attacked without being seen or defended by some other part.

This last method was in use a long while, and would in all appearance have continued to this day, if gunpowder had not been found out: but the violence of the guns and mortars soon convinced the world, that such towers and walls were but a weak defence against these thundering engines; and besides, as the nature of the attack was entirely changed, it was also necessary to change that of fortifying likewise.

From that time, ramparts were added to the walls, the towers enlarged into bastions, and all sorts of outworks have been added, such as ravelins, counterscarps, horn and

crown-works, and others of the like nature, in order to render the defence in some measure equivalent to the attack.

Notwithstanding all the improvements which have been made in the art of fortifying since the invention of gunpowder, that of attacking is still superior to it. Engineers have tried in vain to render the advantages of a fortification equal to those of the attack; the superiority of the besiegers fire, together with the greater number of men, obliges generally, sooner or later, the besieged to submit.

The greatest improvement made in the art of attacking happened in the year 1697, when *M. Vauban* made first use of ricochet firing at the siege of *Atb*, whereby the besieged, placed behind the parapets, were as much exposed to the fire of the besiegers, as if there had been none; whereas before, they had been secure as long as the parapet was not demolished: and the worst is, that there can be no remedy found to prevent this enfilading, without falling into inconveniencies almost as bad as those which we endeavour to avoid.

Although authors agree as to the general form in the present manner of fortifying, yet they mostly differ in particular constructions of the parts: as it would be both needless and

and superfluous to treat of all the different methods hitherto proposed, we shall content ourselves with explaining those only, which are most esteemed by the best judges, and have been mostly put in practice; with adding observations on their perfections and imperfections, and point out how some of the parts may be improved.

As M. *Vauban* had more experience than any other engineer whatsoever, and his methods are mostly used all over *Europe*, we presume it will be more advantageous to beginners to explain his methods first; and then those of Mr. *Coeborn*, who, next to M. *Vauban*, excelled in this art.

M. *Vauban* has given three different methods; the first is that which has been used in the fortifying of most places; the second was used at *Landau* and *Beford*, chiefly designed for places which have a wall or rampart already; and the third has been applied in the fortifying of *New Brisach*; each of these methods will be treated of separately, in their order.

Construction of M. VAUBAN'S first Method.

This method is divided into little, mean, and great; the little is chiefly used in the

THE ELEMENTS

construction of citadels, the mean in that of all forts of towns, and the great in particular cases only.

We shall give the construction of the mean, as being most useful, and refer the reader to the table hereafter, for those dimensions which are different in these several fortifications.

Plate I.
Fig. 1.

Inscribe in a circle a polygon of as many sides as the fortification is designed to have fronts; let AB be one of the sides of half an exagon, which bisect by the perpendicular CD: divide half AC of it into nine equal parts, and one of these into ten others; then these divisions will serve as a scale to construct all the parts of the fortification, and each of them is supposed to be a toise or fathom, that is, six *French* feet; and therefore the whole side AB is supposed to be 180 toises.

As the dividing a line into so many equal parts, is troublesome and tedious, it is more convenient to have a scale of equal parts, by which the works may be constructed.

If therefore, in this case, the radius is taken equal to 180 toises, and the circle described with that radius being divided into six equal parts, or the radius being carried six times round, you will have an exagon inscribed;

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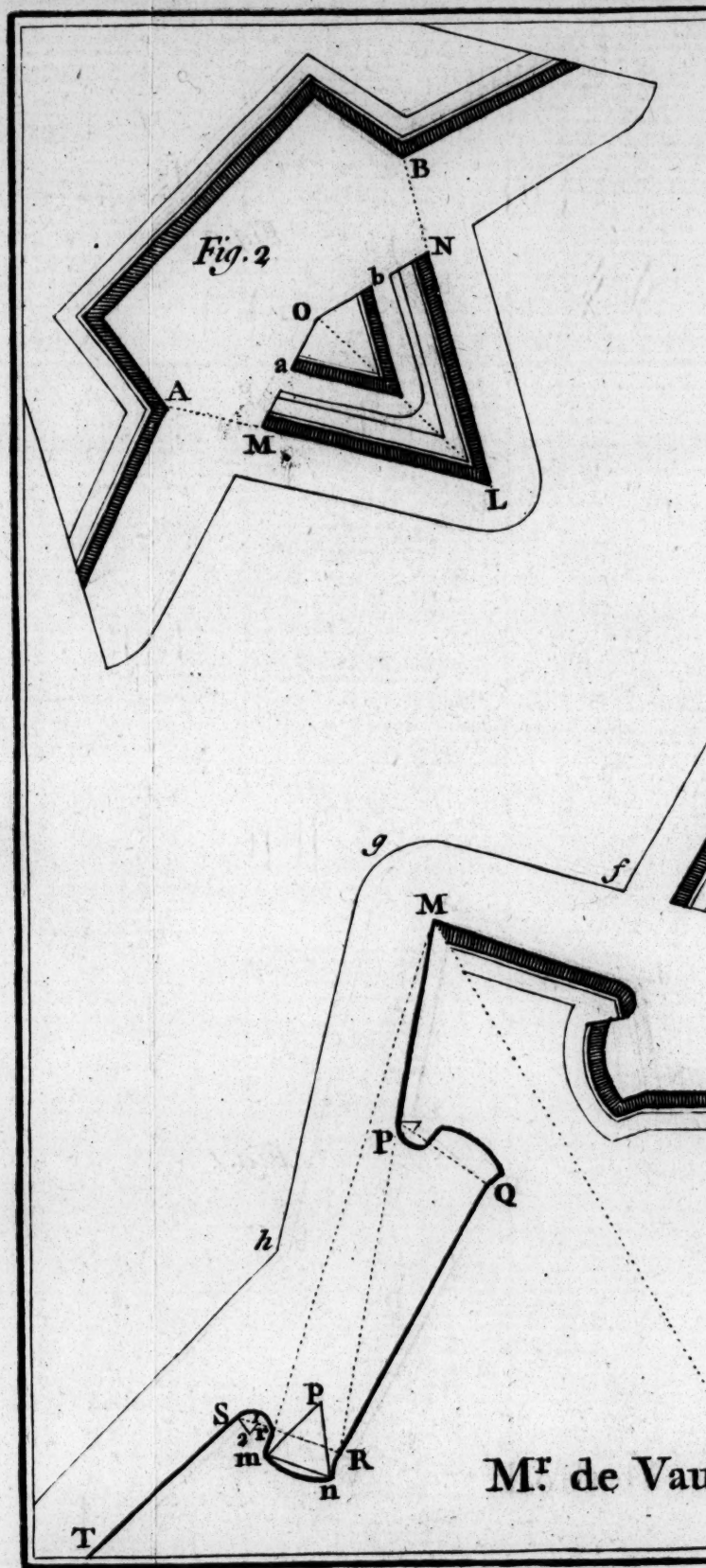
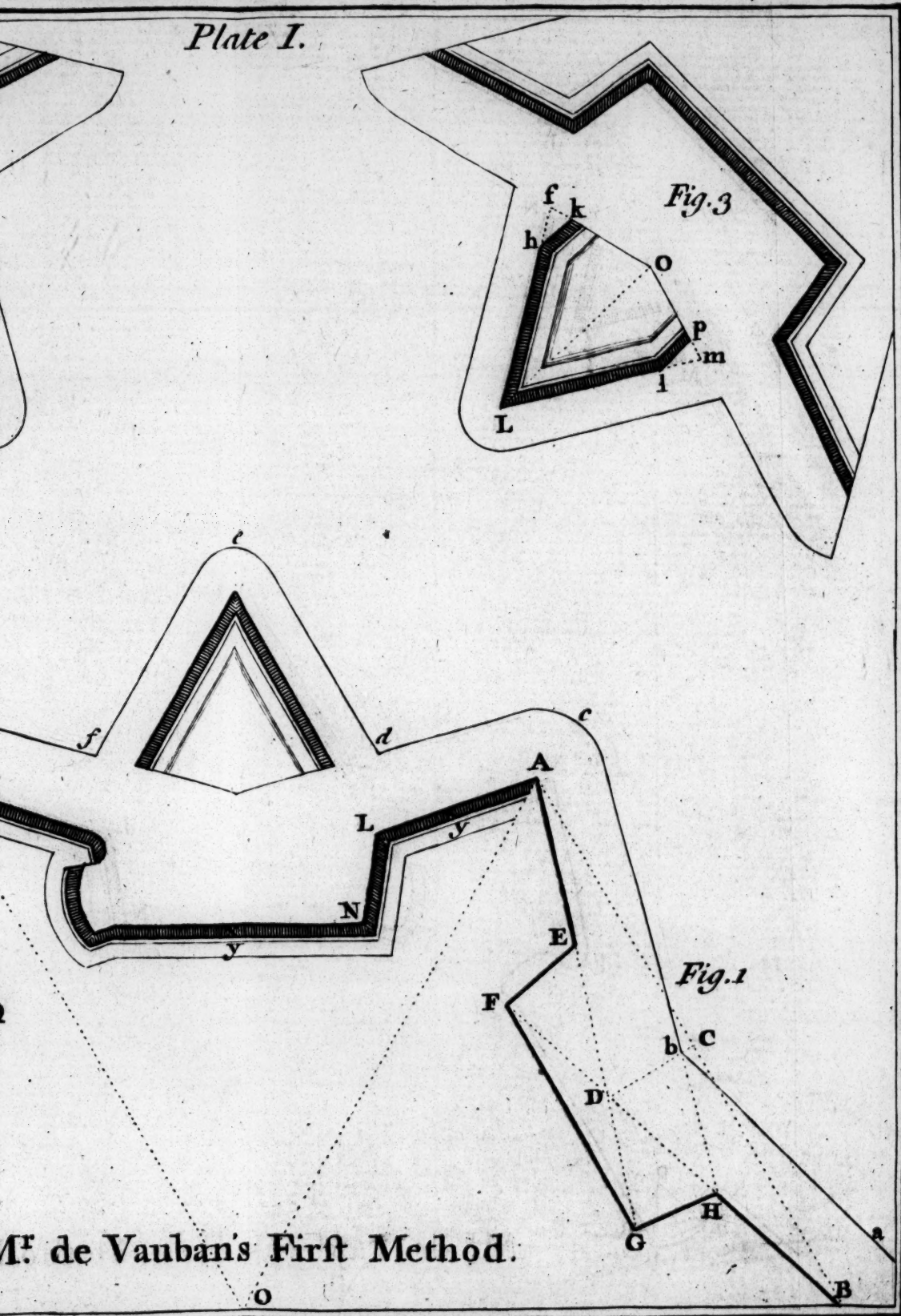
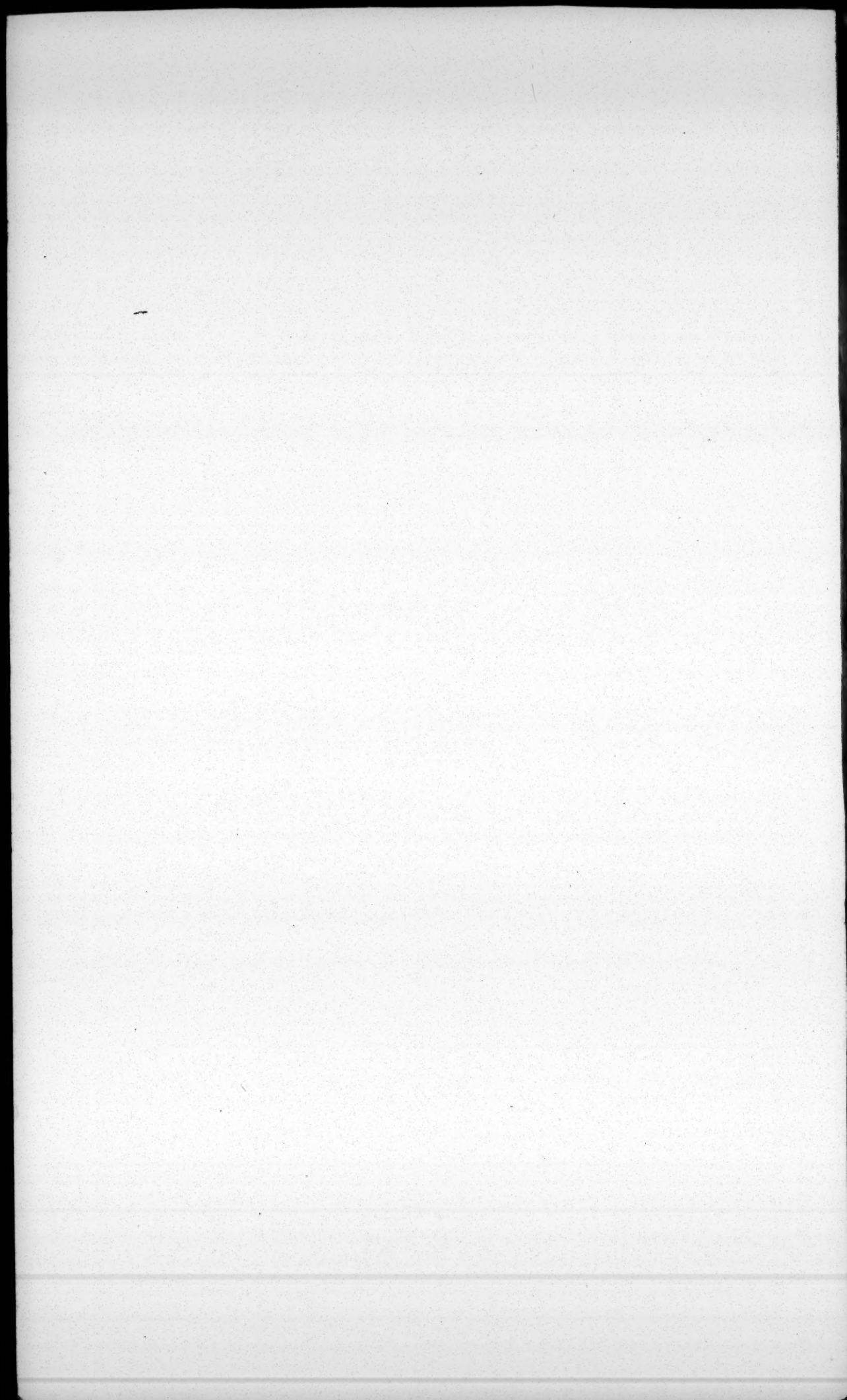


Plate I.





AB being bisected by the perpendicular CD as before, set off 30 toises from C to D, and draw the indefinite lines ADG, BDF, in which take the parts AE, BH, each equal to 50 toises; from the center E describe an arc through the point H, meeting AD in G, and from the center H describe an arc through the point E, meeting BD in F; or which is the same, make each of the lines EG, HF, equal to the distance EH; then the lines joining the points A, E, F, G, H, B, will be the principal or outline of the front.

If the same construction be performed on the other sides of the polygon, you will have the principal or outline of the whole fortification.

If, with a radius of 20 toises, there be described circular arcs, from the angular points B, A, M, T, and lines are drawn from the opposite angles E, H, &c. so as to touch these arcs, their parts a b, b c, &c. together with these arcs, will represent the outline of the ditch.

N. B. In any other polygon, besides the exagon, the radius cannot be equal to 180 toises; and in that case the radius must be found, so as to answer to a given side of 180 toises, by Problem 14.

DE-

DEFINITIONS.

1. The part FEALN, is called the *bastion*.
2. AE, AL, the *faces* of the bastion.
3. EF, LN, the *flanks*.
4. FG, the *curtain*.
5. FN, the *gorge* of the bastion.
6. AG, BF, the *lines of defence*.
7. AB, the *exterior side of the polygon*.
8. CD, the *perpendicular*.
9. Any line which divides a work into two equal parts, is called the *capital* of that work.
10. abc, the *counterscarp* of the ditch.
11. A,M, the *flanked angles*.
12. H,E,L, the angles of the *shoulder*, or *shoulder only*.
13. G,F,N, the *angles of the flank*.
14. Any angle whose point turns from the place, is called a *saliant angle*, such as A,M; and any angle whose point turns towards the place, *re-entering angle*, such as b,F,N.
15. If there be drawn two lines parallel to the principal or outline, the one at 3 toises distance, and the other at 8 from it; then the space yx included between the principal one, and that farthest distant, is called the *rampart*.

And

And the space xx, contained by the principal line, and that next to it, and which is generally stained black, is called the *parapet*.

16. There is a fine line drawn within four feet of the parapet, which expresses a step called *banquette*.

N. B. All works have a parapet of three toises thick, and a rampart of 8 to 10, besides their slopes. The rampart is elevated more or less above the level of the place, from 10 to 20 feet, according as the nature of the ground is, and according to the particular constructions of engineers.

The parapet is a part of the rampart elevated from 6 to $7\frac{1}{2}$ feet above the rest, in order to cover the troops, which are drawn up there, from the fire of the enemy in a siege; and the banquette is two or three feet higher than the rampart, or about four feet lower than the parapet; so that when the troops stand upon it, they may just be able to fire over the parapet.

17. The body of the place, is all that which is contained within this first rampart; for which reason, it is often said to construct the body of the place; which means properly, the construction of the bastions and curtains.

18. AH

THE ELEMENTS

18. All the works which are constructed beyond the ditch, before the body of the place, are called *outworks*.

TABLE.

	Forts.							Little Fortif.			Mean		Great	
	80	90	100	110	120	130	140	150	160	170	180	190	200	260
Side of Polyg.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Perpendiculars	10	11	12½	14	15	16	20	21	23	25	30	31	25	22
Faces bast.	22	25	28	30	33	35	40	42	45	47	50	53	55	60
Cap. of ravel.	25	28	30	35	38	40	45	50	50	52	55	55	60	50

In the first vertical column are the numbers expressing the lengths of the exterior sides from 80 to 260.

In

In the second, the perpendiculars answering to these sides.

In the third, the lengths of the faces of the bastions ; and in the fourth, the lengths of the capitals of the ravelins.

The forts are mostly, if not always, squares, for which reason, the perpendiculars are made one eighth of the exterior sides ; because, if they were more, the gorges of the bastions would become too narrow.

The little fortification, is chiefly designed for citadels, and are commonly pentagons ; the perpendiculars are made one seventh of the exterior side ; the mean is used in all kinds of fortifications, from an exagon upwards to any number of sides ; and the great is seldom used but in an irregular fortification, where there are some sides that cannot be made less without much expence ; or in a town which lies near a great river, where the side next the river is made from 200 to 260 toises ; and as that side is less exposed to be attacked than any other, the perpendicular is made shorter, which saves much expence.

The faces of the bastions are all $\frac{2}{7}$ ths of the exterior sides, or nearly so, because the fractions are neglected.

It

It may be observed in general, that in all squares the perpendicular is $\frac{1}{8}$ th of the exterior side, in all pentagons $\frac{1}{7}$ th, and in all the rest upwards $\frac{1}{6}$ th.

Construction of Orillons and retired Flanks.

Describe the front MPQRST as before, and divide the flank into three equal parts, of which suppose Sr to be one: from the opposite flanked angle M, draw a line Mr, in which take the part mr of 5 toises; take likewise Rn in the line of defence MR, produced, equal to 5 toises, and join nm, upon which as a base describe the equilateral triangle npm, and from the angle p, opposite to the base as center, is described the circular flank, nm.

And if Sr be bisected by the perpendicular, 1, 2, and another be erected upon the face ST, at S; the intersection 2 of these two perpendiculars, will be the center of the arc which forms the orillon.

The orillons are very useful in covering the retired flanks, which cannot be seen but directly in the front; and as these orillons are round, they cannot be so easily destroyed

as

as they would be, if they were of any other figure. But for what reason the retired flanks are made of such circular arcs as these, is not possible to be guess at; since it may easily be proved, as we shall do in the third section, that the flank made upon the chord of that arc would be much better, and is at the same time of less expence.

But what is more strange, that most engineers look upon these flanks as the best that could have been thought of, and they use them in all fortifications, which they propose as the best models: there can be given no other reason of this opinion, than the unaccountable fancy, of mankind in general, for novelty; and their indolence to receive from others, things for true, rather than to inquire whether they be so or not.

Construction of Ravelins or Half-moons.

Set off 50 toises, from the re-entering angle Fig. 2. O of the counterscarp, on the capital, OL of the ravelin, or on the perpendicular produced, and from the point L draw lines to the shoulders A, B; whose parts LM, LN, terminated by the counterscarp, will be the faces MO, ON, the semi-gorges of the ravelin required. This

THE ELEMENTS

This is M. *Vauban's* method of constructing ravelins, according to some authors; and others will have the faces of the ravelin to terminate on those of the bastions within 3 toises of the shoulders; which seems to be the best way, for the ravelins cover the flanks much better than the others.

The ditch before the ravelin is 12 toises, its counterscarp parallel to the faces of the ravelins, and is made in a circular arc, before the saliant angle; as likewise all ditches are in general.

When the ravelins are made with flanks, as in figure 3, the faces should terminate of those of the bastions, at least 5 toises from the shoulders.

The flanks are made by setting of 10 toises from the extremities of the faces, from *f* to *h*, and from *m* to *l*, and from the points *h*, *l*, the flanks *h k*, *l p*, are drawn parallel to the capital *LO* of the ravelin.

There are sometimes redoubts made in the ravelin, such as in fig. 2. which is done by setting of 16 toises from the extremities of the faces on the semi-gorges from *N* to *b*, and from *M* to *a*; and from the points *b*, *a*, the faces are drawn parallel to those of the ravelin: the ditch before this redoubt is 6 toises, and its counterscarp parallel to the faces. *Con-*

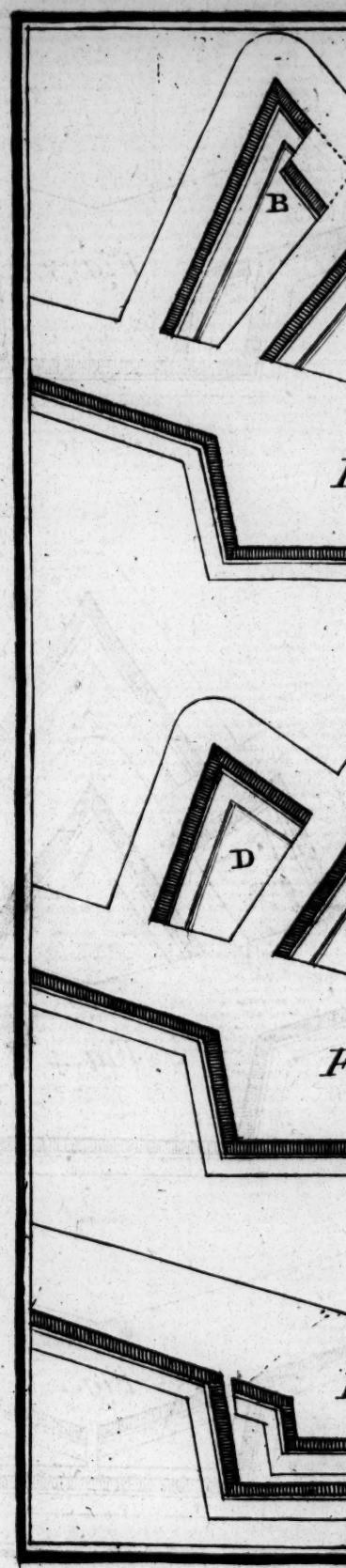
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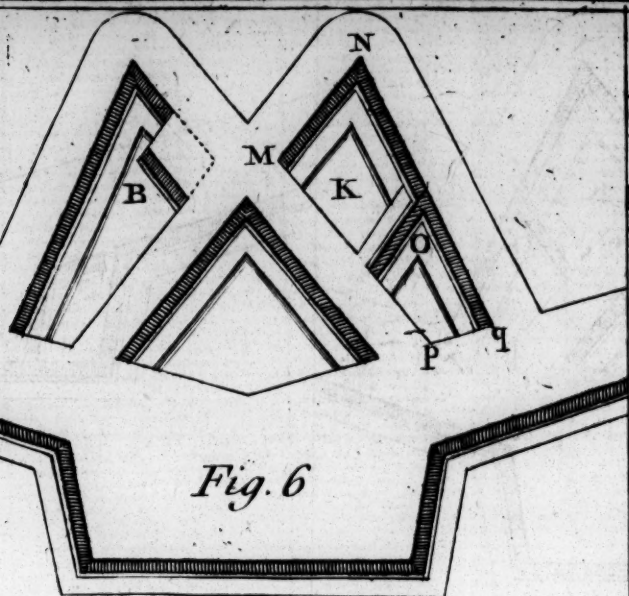


Fig. 6

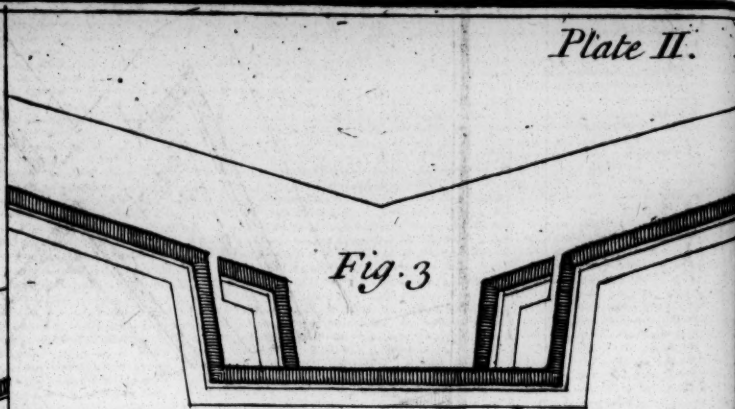


Fig. 3

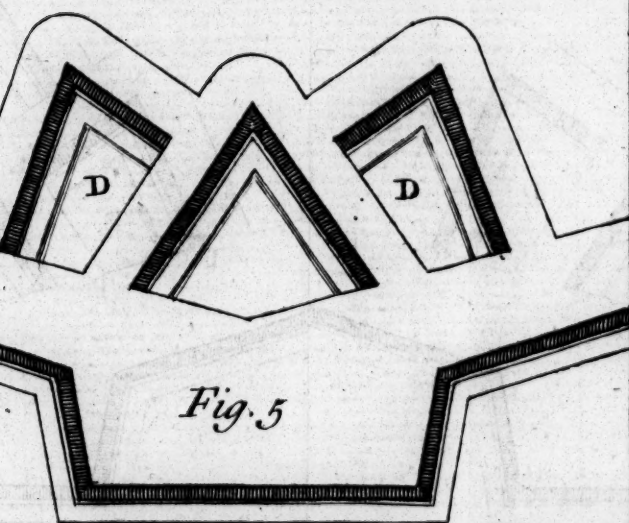


Fig. 5

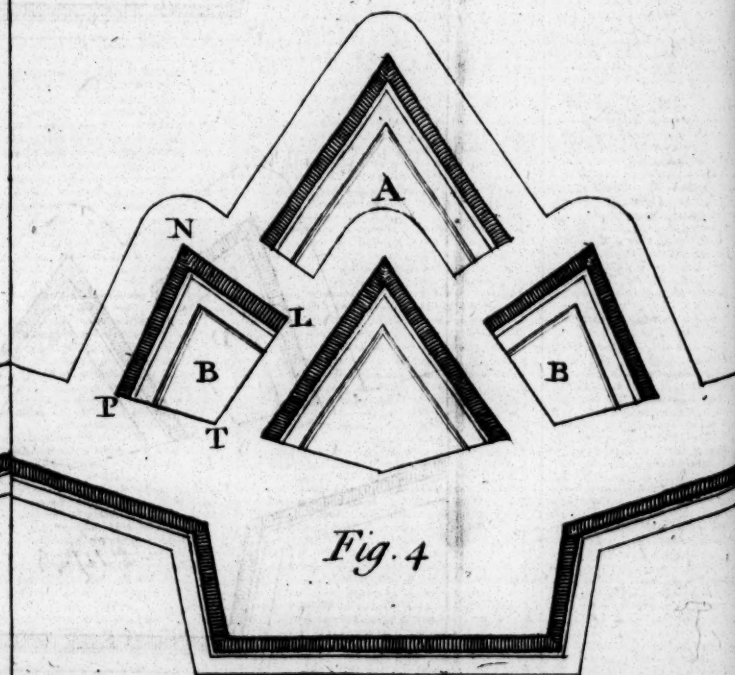


Fig. 4

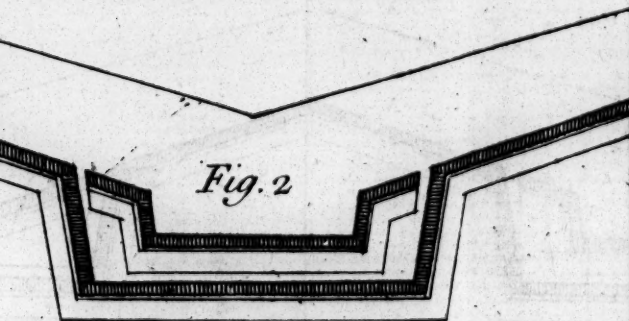


Fig. 2

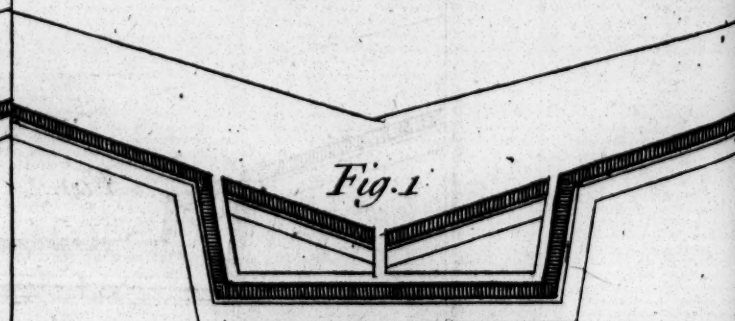


Fig. 1

Construction of Tenailles.

A tenaille is a work made in the ditch before the curtains, the parapet of which is only 2 or 3 feet higher than the level ground of the ravelin. There are three different forts; the first are those as in fig. 1, which are made in the direction of the lines of defence, leaving a passage of 3 toises between their extremities and the flanks of the bastions, as likewise another of 2 in the middle for a bridge of communication to the ravelin.

Plate II.
Fig. 1, 2, 3.

The second fort, are those as in fig. 2.; their faces are in the lines of defences, and 16 toises long, besides the passage of 3 toises between them and the flanks of the bastions; their flanks are found by describing arcs from one shoulder of the tenaille as center through the other, on which are set off 10 toises for the flanks desired.

And the third fort, are those as in fig. 3; their faces are 16 toises, as in the second fort, and the flanks are parallel to those of the bastions.

The use in general of tenailles, is to defend the bottom of the ditch by a grazing
D fire,

fire, as likewise the level ground of the ravelin, and especially the ditch before the redoubt within the ravelin, which can be defended from no where else, so well as from them.

The first fort do not defend the ditch so well as the others, as being too oblique a defence; but as they are not subject to be enfiladed, M. *Vauban* has generally preferred them in the fortifying of places, as may be seen in the citadel of *Lille*, at *Landau*, *New Brisach*, and in a great many other places.

The second fort defend the ditch much better than the first, and add a low flank to those of the bastions; but as these flanks are liable to be enfiladed, they have not been much put in practice. This defect might however be remedied, by making them so, as to be covered by the extremities of the parapets of the opposite ravelins, or by some other work.

As to the third fort, they have the same advantage as the second, and are likewise liable to the same objections; for which reason they may be used with the same precautions, which have been mentioned in the second.

Tenailles

Tenailles are esteemed so necessary, that there is hardly any place fortified without them, and it is not without reason; for when the ditch is dry, the part behind the tenailles serves as a place of arms, from which the troops may sally, destroy the works of the enemy in the ditch, oppose their descent, and retire with safety; and the communication from the body of the place to the ravelin becomes easy and secure, which is a great advantage; for by that means the ravelin may make a much better defence, as it can be supplied with troops and necessaries at any time. And if the ditch is wet, they serve as harbours for boats, which may carry out armed men to oppose the passage over the ditch whenever they please; and the communication from the tenailles to the ravelin, becomes likewise much easier than it would be without them.

Construction of Lunettes.

Lunettes are placed on both sides of the ravelin, such as B, to increase the strength of a place; they are constructed, by bisecting the faces of the ravelin with the perpendicular LN, on which is set off 30 toises from the

Fig. 4.

D 2

coun-

counterfcarp of the ditch, for one of its faces ; the other face PN, is found by making the semi-gorge TP of 25 toises ; the ditch before the lunettes is 12 toises, the parapet 3, and the rampart 8 ; as in the ravelin.

There is sometimes another work made to cover the saliant angle of the ravelin, such as A, called *Bonnet*, whose faces are parallel to those of the ravelin, and when produced bisect those of the lunettes ; the ditch before it is 10 toises.

Fig. 5.

There are likewise lunettes, such as D, in fig. 5, whose faces are drawn perpendicular to those of the ravelin, within a third part from the saliant angle ; and their semi-gorges are only 20 toises.

These kind of works may make a good defence, and are no very great expence ; for as they are so near the ravelin, the communication with it is very easy, and one cannot well be maintained, till they are all three taken.

I would have the face PN (fig. B) perpendicular to that of the bastion, which would then defend it in a direct manner ; and if the semi-gorges of the bonnet A were only 7 or 8 toises, it would become less expensive, and its ditch and the covert-way before it would be better defended by the lunettes.

Con-

Construction of Tenaillons.

Produce the faces of the ravelin beyond Fig. 6. the counterscarp of the ditch, at a distance MN of 30 toises, and take on the counterscarp of the great ditch, 15 toises from the re-entering angle p to q, and draw Nq; then qNMP will be the tenaillon required; its ditch is 12 toises, that is, the same as that of the ravelin. Sometimes there is made a retired battery, in the front of the tenaillons, as in fig. B; this battery is 10 toises from the front to which it is parallel, and 15 toises long.

There are commonly retrenchments made in the tenaillons, such as O; their parapets are parallel to the fronts MN, or rather perpendicular to the side Nq, and bisect the side qN; the ditch before this retrenchment is 3 toises, and there is a banquette before the parapet, next to the ditch, of about 8 feet, called *Berm*; it serves to prevent the earth of the parapet (which seldom has any revetement) from falling into the ditch.

It is to be observed, that the ravelin, before which tenaillons are constructed, must have its salient angle much greater than the former construction makes them; otherwise

the saliant angles of the tenaillons become too acute, for which reason we made the capital of this ravelin 45 toises, and the faces terminate within 3 toises of the shoulders.

Construction of Counterguards.

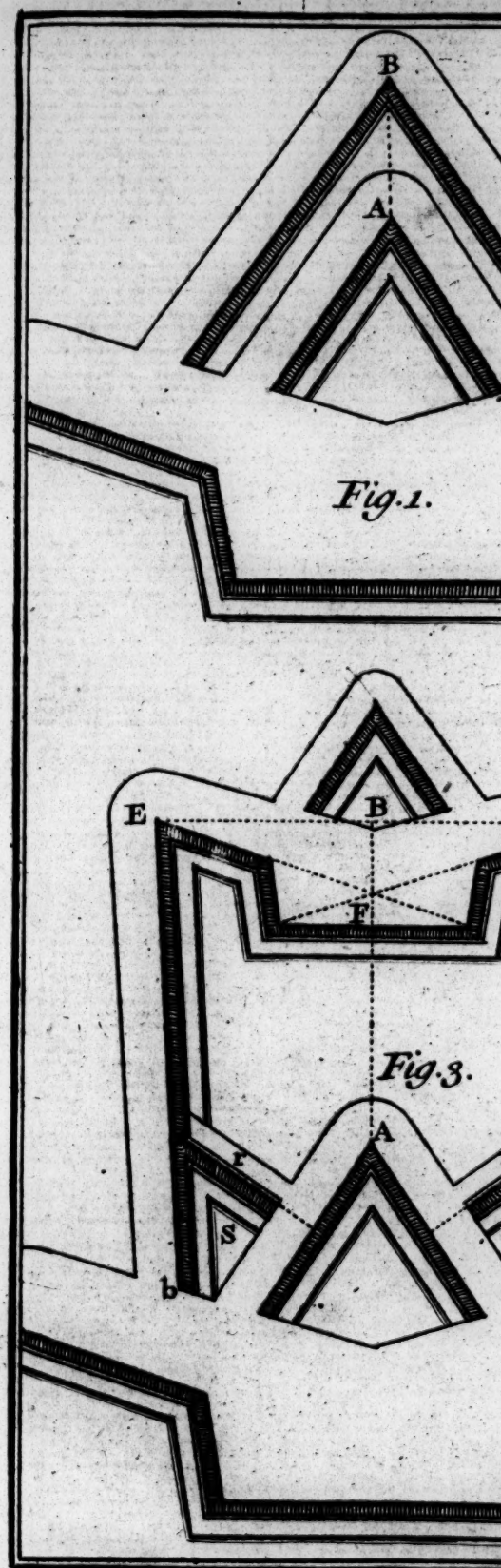
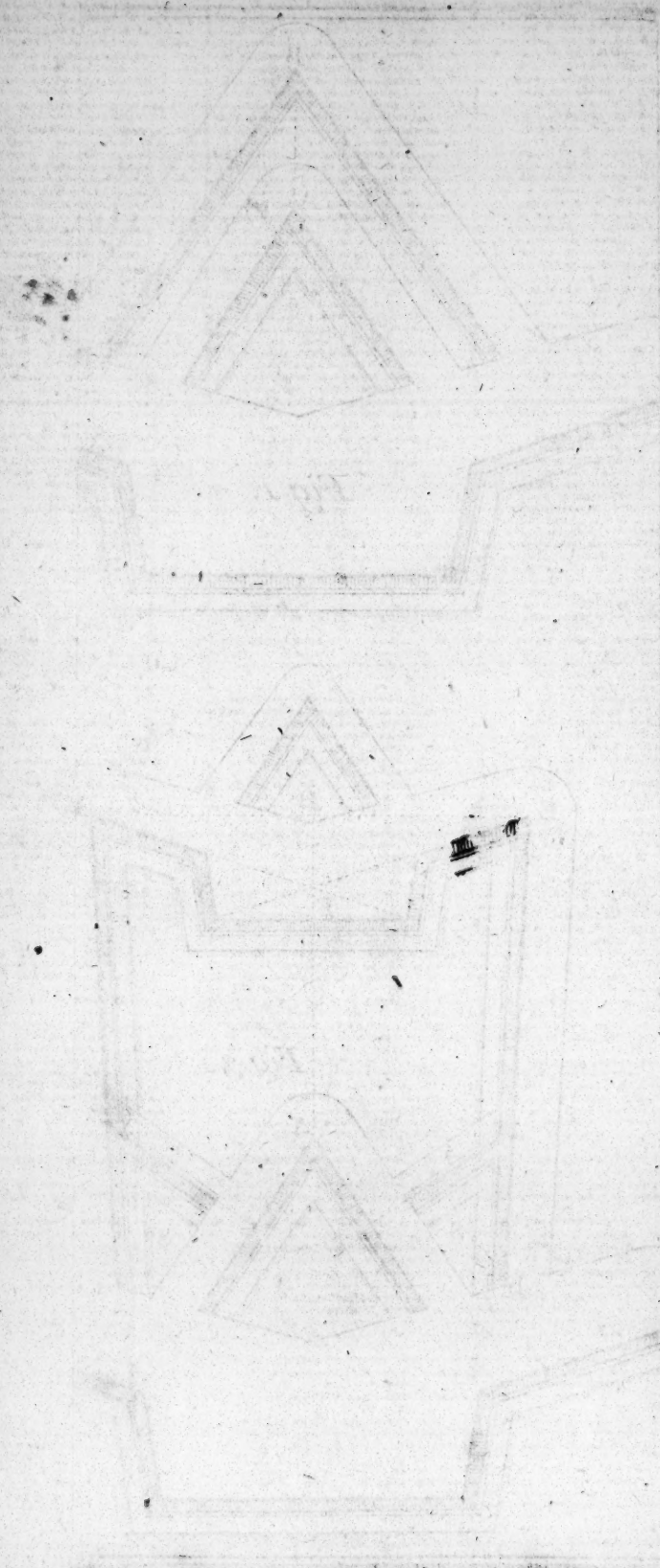
Plate III. When the counterguard is placed before Fig. 1, 2. the ravelin, set off 40 toises on the capital of the ravelin from the saliant angle A, to the saliant angle B, of the counterguard; and 10 from C to D, on the counterscarp of the ditch.

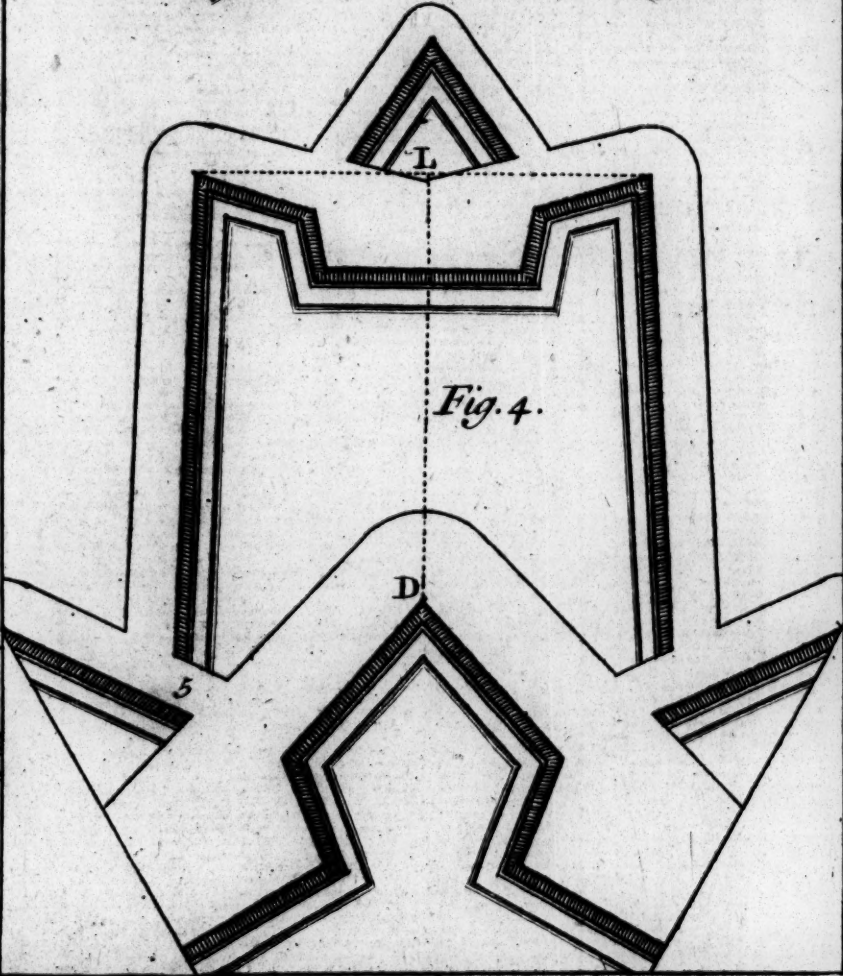
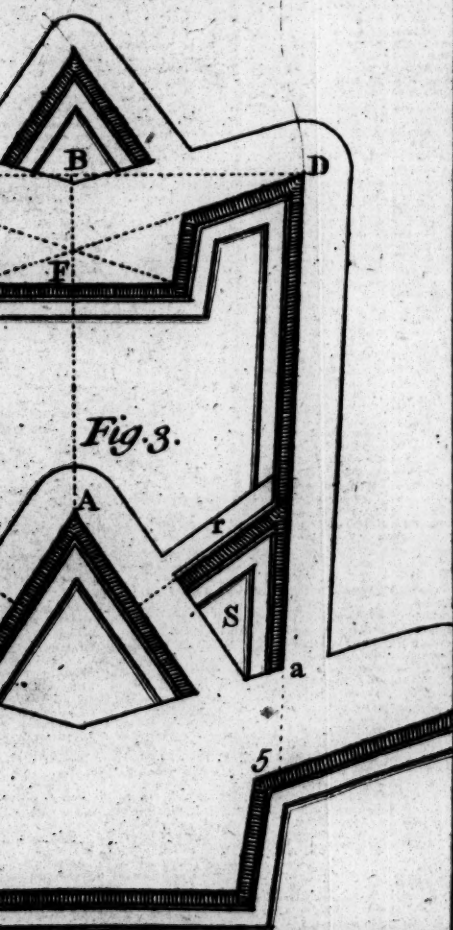
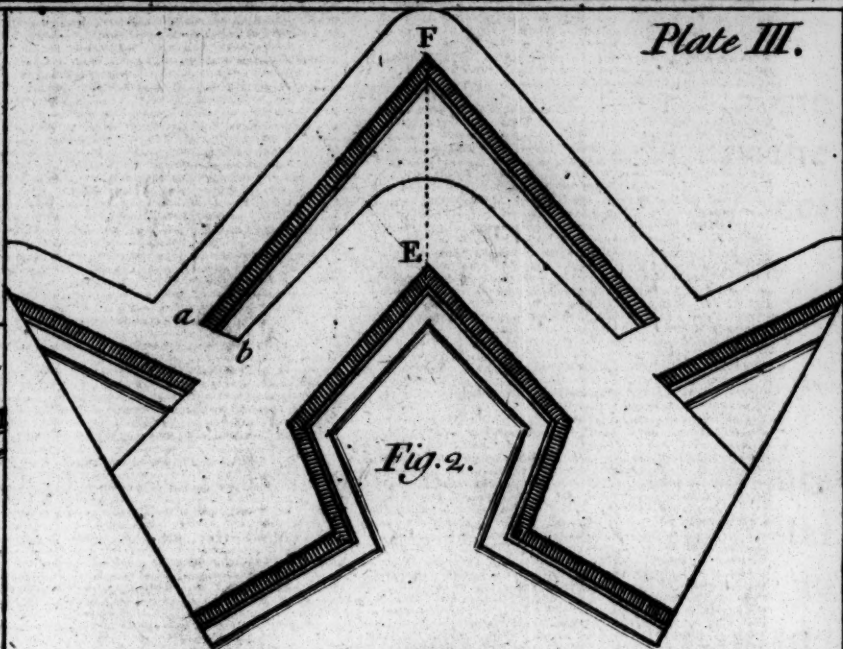
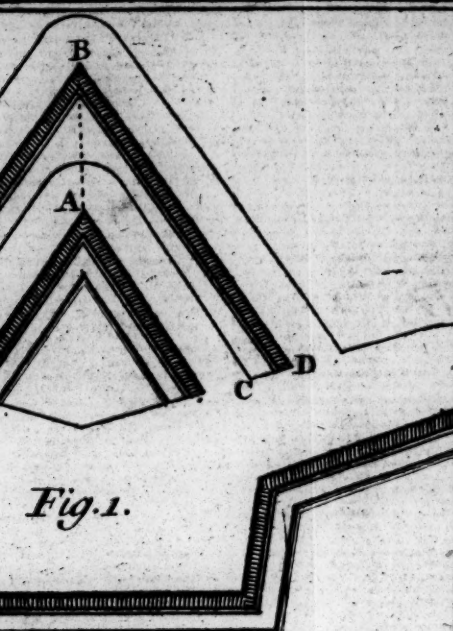
When the counterguard is before the bastion, such as in fig. 2, its saliant angle F is 50 toises from the saliant angle E of the bastion, and the breadth near the ditch of the ravelin is 10 toises as before.

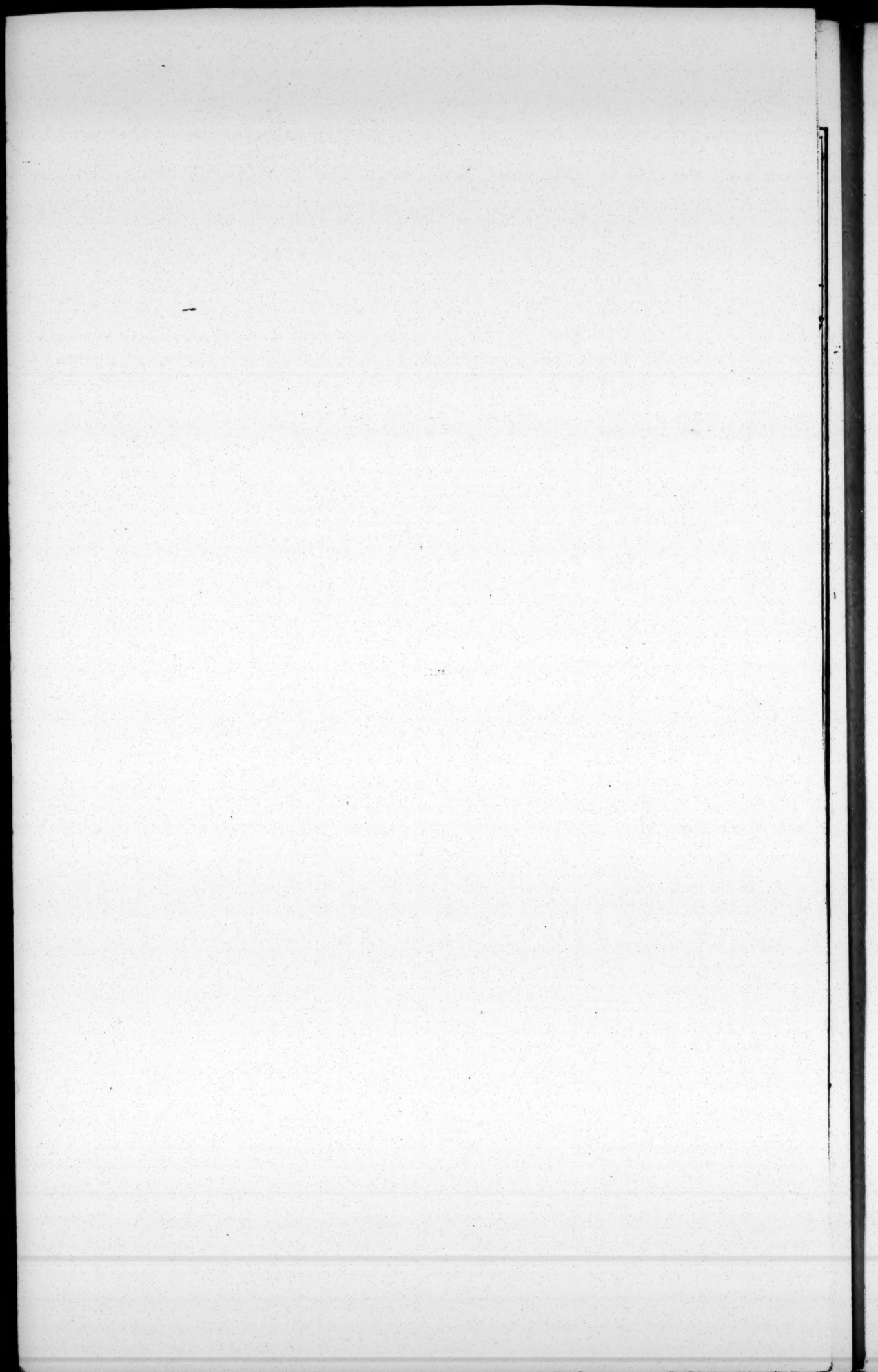
The ditch before the counterguards is 12 toises, and its counterscarp parallel to the faces.

Counterguards are made before the ravelin, in some particular occasions only, but are frequently constructed before the bastions; as covering the flanks wonderfully well. Some authors, as *Blondel*, and *M. Coehorn*, will have them much narrower than they are here.

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Construction of Hornworks.

Produce the capital of the ravelin beyond Fig. 3. the salient angle A, at a distance AB of about 80 toises; draw DBE, at right angles to AB; in which take BD, BE, each equal to 55 toises; and on the exterior side DE, trace a front of a polygon in the same manner as that of the body of the place, making the perpendicular BF 18 toises; and the faces 30.

The branches Da, Eb, of the hornwork, when produced, terminate on the faces of the bastions, within 5 toises of the shoulders. The ditch of the hornwork is 12 toises, and its counterscarp parallel to the branches; and in the front terminates at the shoulders, in the same manner as the great ditch before the bastions.

The capital of the ravelin before the front of the hornwork is 35 toises, and the faces terminate on the shoulders, or rather 2 or 3 toises beyond them; and the ditch before the ravelin is 8 toises.

There are sometimes retrenchments made within the hornwork, such as S, S; which are constructed by erecting perpendiculars to

D 4

the

the faces of the ravelins, within 25 toises of their extremities. This retrenchment, like all others, has a parapet turfed only with a berm of 8 feet before it; as likewise a ditch from 3 to 5 toises broad.

Fig. 4. When a hornwork is made before the bastion; the distance DL, of the front from the salient angle of the bastion, is 100 toises; and the branches terminate on the faces of the adjacent ravelins within 5 toises from their extremities; all the rest the same as before.

Construction of Crownworks.

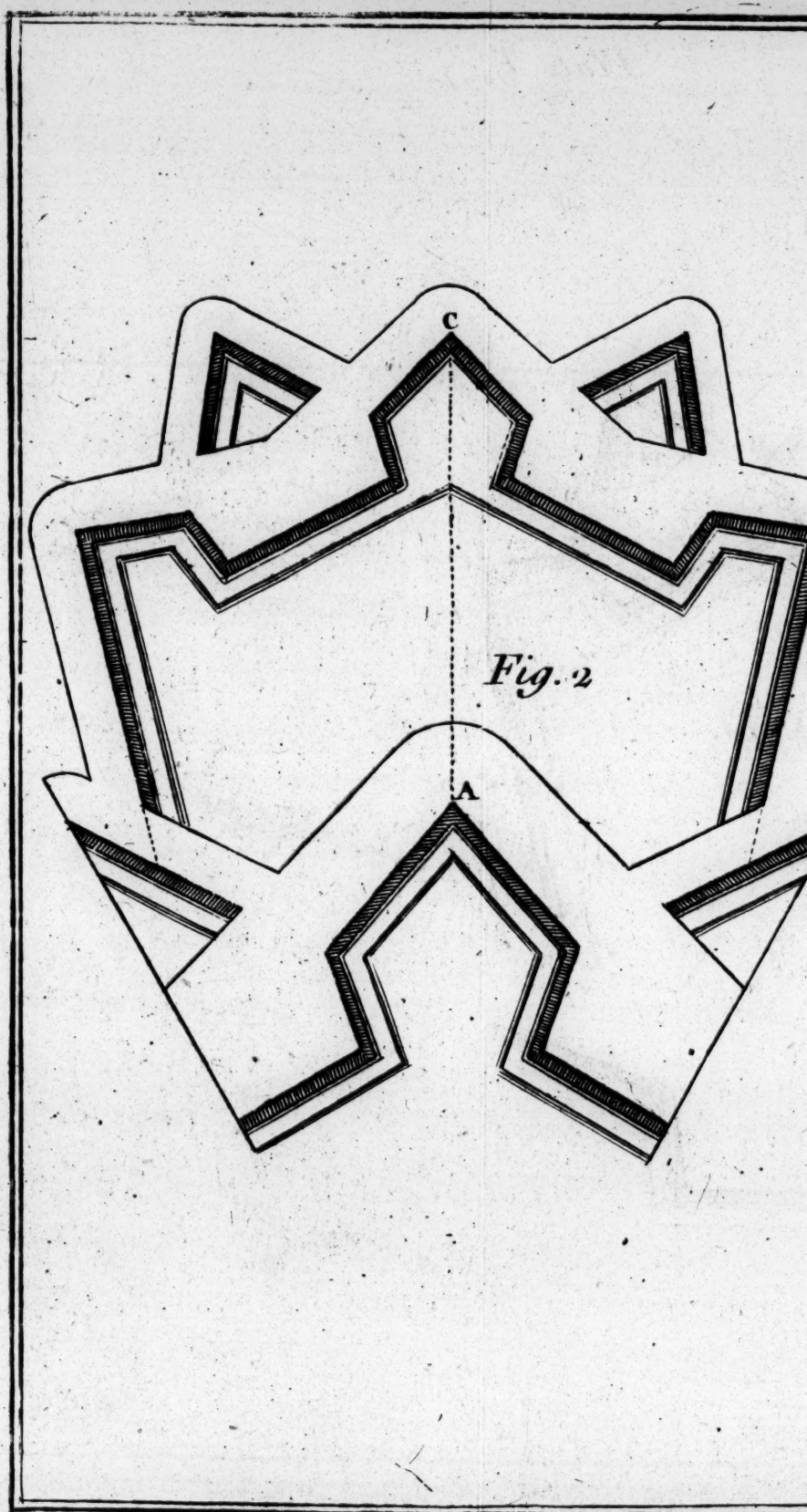
Plate IV. Fig. 1. From the salient angle A of the ravelin, as a center, describe an arc of a circle with a radius of about 120 toises, cutting the capital of the ravelin produced at C; from the point C set off the cords CB, CF, each of them equal to 110 toises, and on each of which, as an exterior side, construct a front of a polygon of the same dimensions as in the hornwork; that is, the perpendicular should be 18 toises, the faces 30, and the branches terminate on the faces of the bastions, within 25 toises of the shoulders.

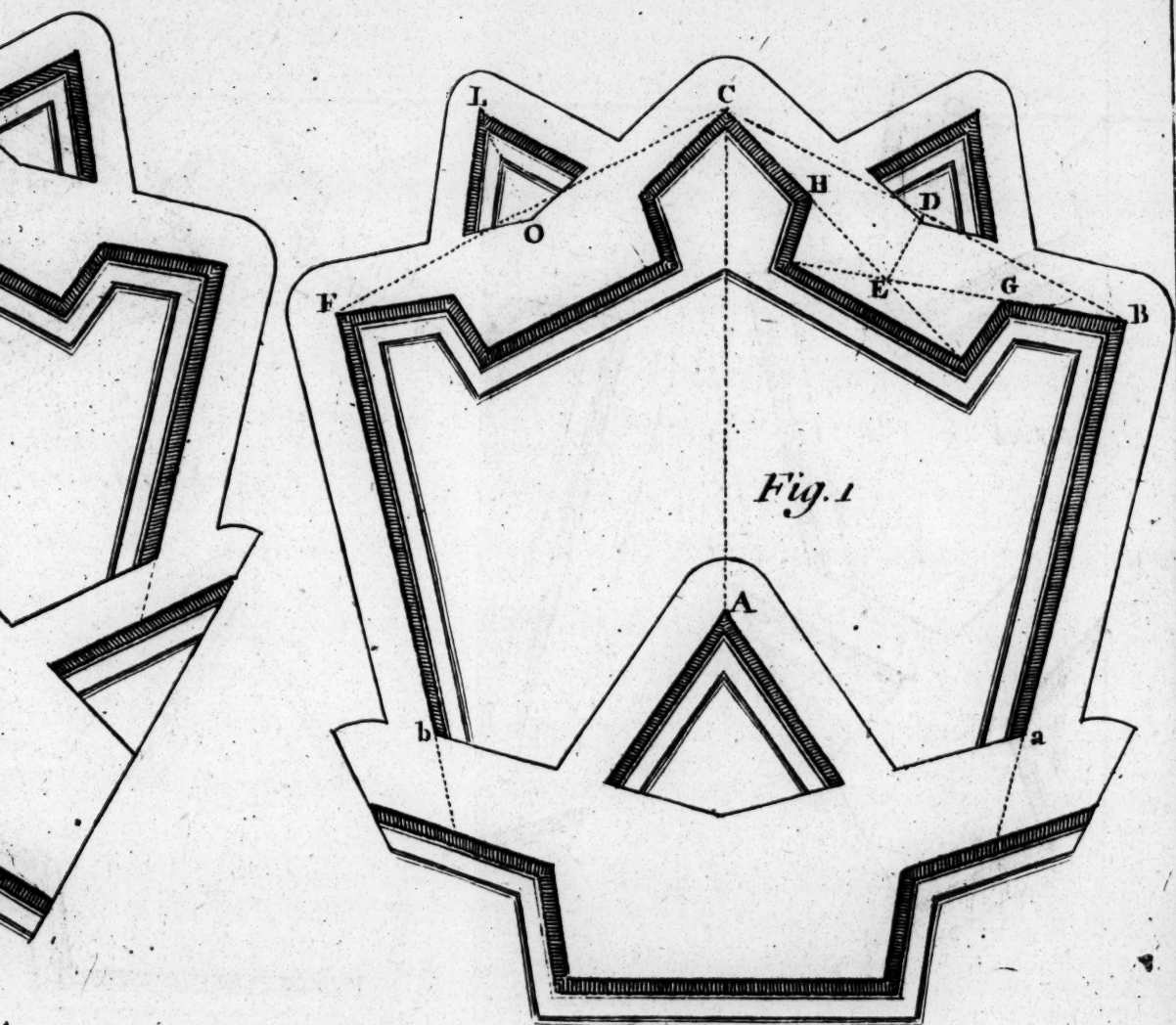
The ditch is 12 toises, the capital of the ravelin 35, and its ditch 8; that is, the same as in the hornwork. Some-

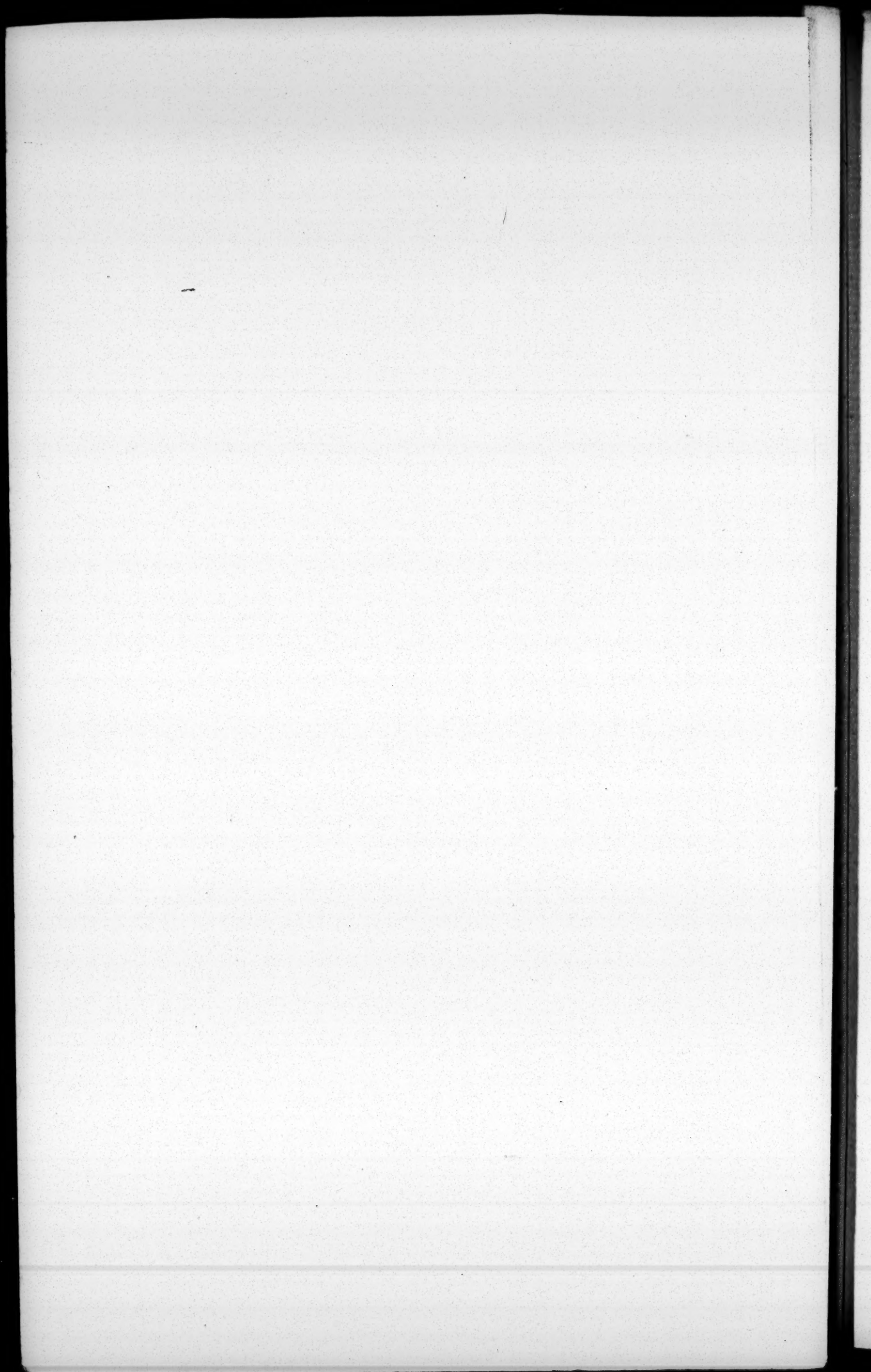
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Sometimes the crownwork is made before the bastion, as in fig. 2; the arc is described from the salient angle A, of the bastion, with a radius of 120 toises, as before, and the branches terminate on the faces of the adjacent ravelins, within 25 toises of their extremities; the rest of the dimensions and constructions are the same as before. Fig. 2.

Hornworks, as well as crownworks, are never made, but when a large spot of ground falls beyond the fortification, which might be advantageous to an enemy in a siege, or to cover some gate or entrance into a town; they have notwithstanding been used without judgment in several places, as at *Tournay*, *Ipres*, &c. Their advantages and disadvantages shall be fully discussed in the third section.

Construction of Covert-ways and Glacis.

Although we have not hitherto mentioned the covert-way, nevertheless, all fortifications whatsoever have one; for they are esteemed to be one of the most essential parts of a modern fortification; and it is certain, the taking the covert-way, when it is in good condition and well defended, is generally

generally the most bloody action of the siege.

Plate V.

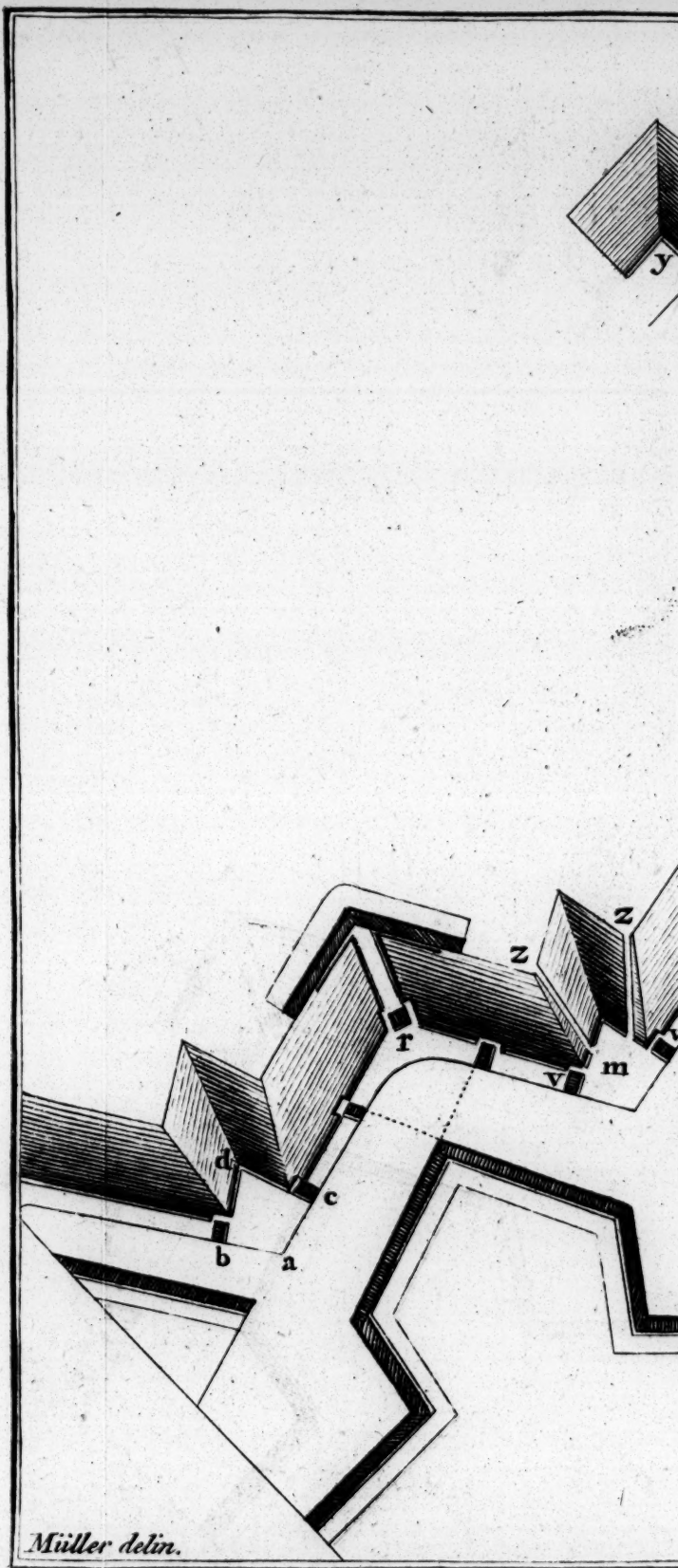
After having constructed the body of the place, and all the outworks which are thought necessary, lines are drawn parallel to the outmost counterscarps of the ditches, at 6 toises distant from it; and the space $mnmn$, included between that line and the counterscarp, will be the covert-way required.

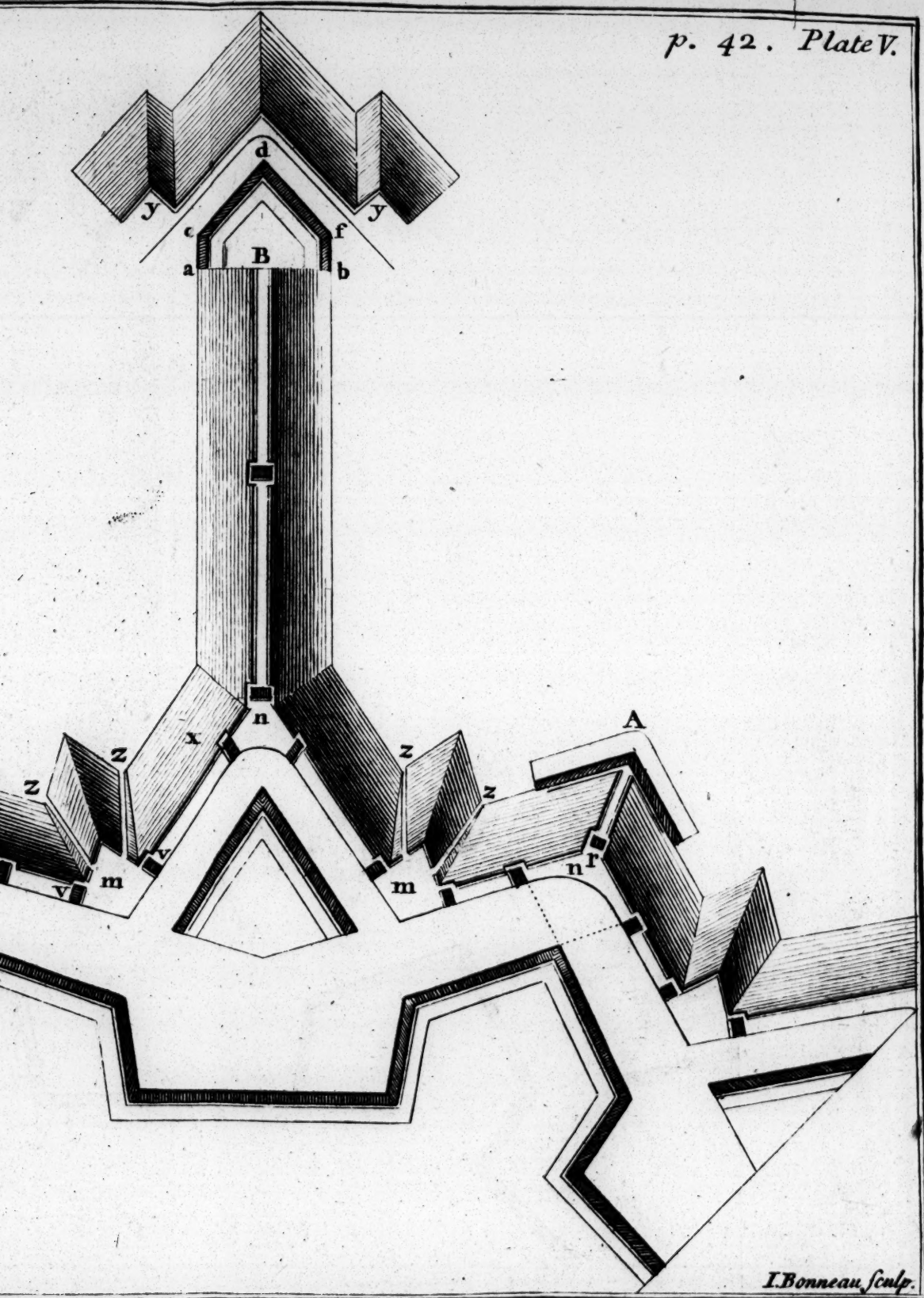
There is in every re-entering angle of the counterscarp a place of arms, m ; which is found by setting off 20 toises from the re-entering angle a , on both sides from a to b , and from a to c ; and from the points b, c , as centers, arcs are described with a radius of 25 toises, so as to intersect each other in d ; then the lines drawn from this intersection to the points b, c , will be the faces of the places of arms.

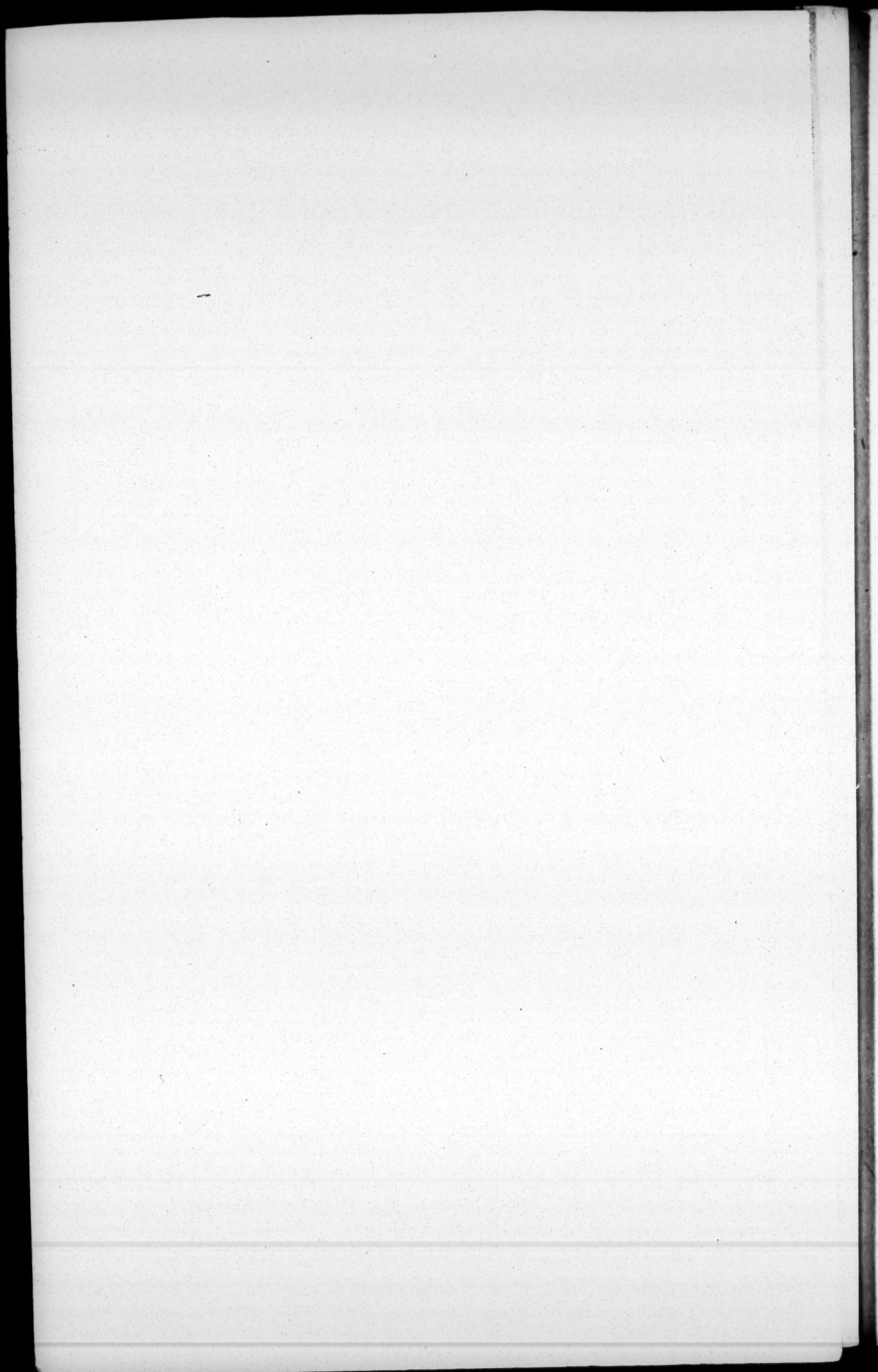
If lines are drawn, parallel to the lines which terminate the covert-way, and the places of arms, at 20 toises distant from them, the space x, x, x , between these lines and those which terminate the covert-way, will be the glacis.

At the extremities of the places of arms, are traverses made, such as v, v , which serve to inclose them; these traverses are 3 toises thick,

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thick, and as long as the covert-way is broad, and a passage is cut in the glacis round them, of about 6 or 8 feet, in order to have a free communication with the rest of the covert-way.

There are also traverses of the same dimensions before every salient angle of the bastion and outworks, and are in the same direction of the faces of those works produced; and the thickness lies at the same side as the parapets.

The passages round these last traverses are likewise from 6 to 8 feet wide.

In each place of arms are two sally-ports z, z, which are 10 or 12 feet wide, for the troops to sally out; in time of a siege they are shut up, with barriers or gates.

Construction of Arrows, and detached Redoubts.

An arrow is a work made before the salient angles of the glacis, such as A; it is composed of a parapet of 3 toises thick, and 40 long, and the ditch before it 5 toises, terminating in a slope at both ends. The communication from the covert-way into these arrows, is 4 or 5 toises wide, and there

THE ELEMENTS

there is a traverse *r* at the entrance of 3 toises thick, with a passage of 6 or 8 feet round it.

A detached redoubt is a kind of work much like a ravelin, with flanks, placed beyond the glacis, such as fig. B; they are made in order to occupy some spot of ground which might be advantageous to the besiegers; likewise to oblige the enemy to open their trenches farther off than they would do otherwise.

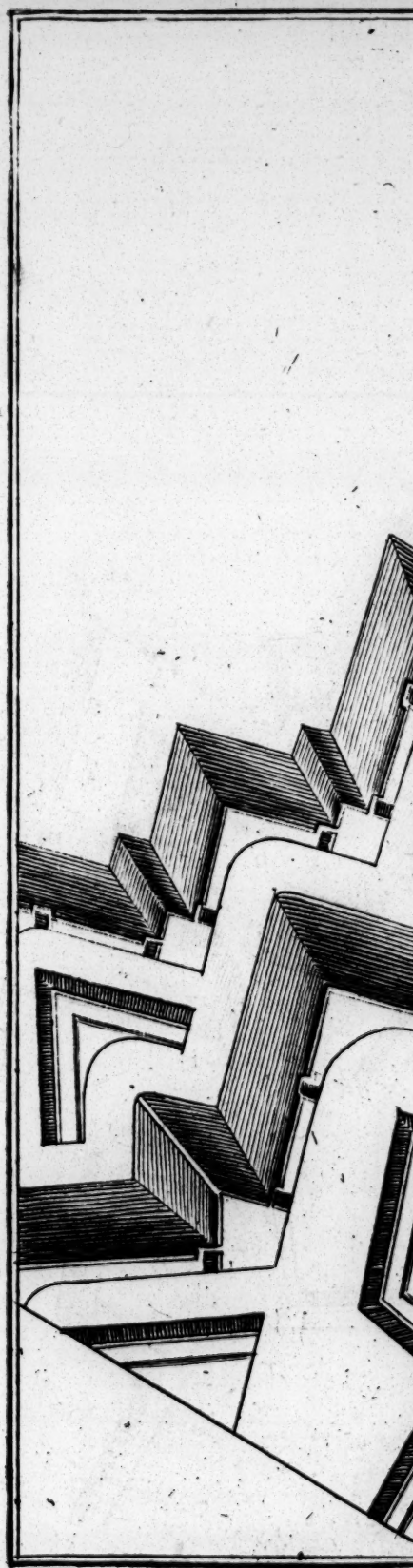
Their distance from the covert-way ought not to exceed 120 toises, that it may be defended by musket-shot from thence.

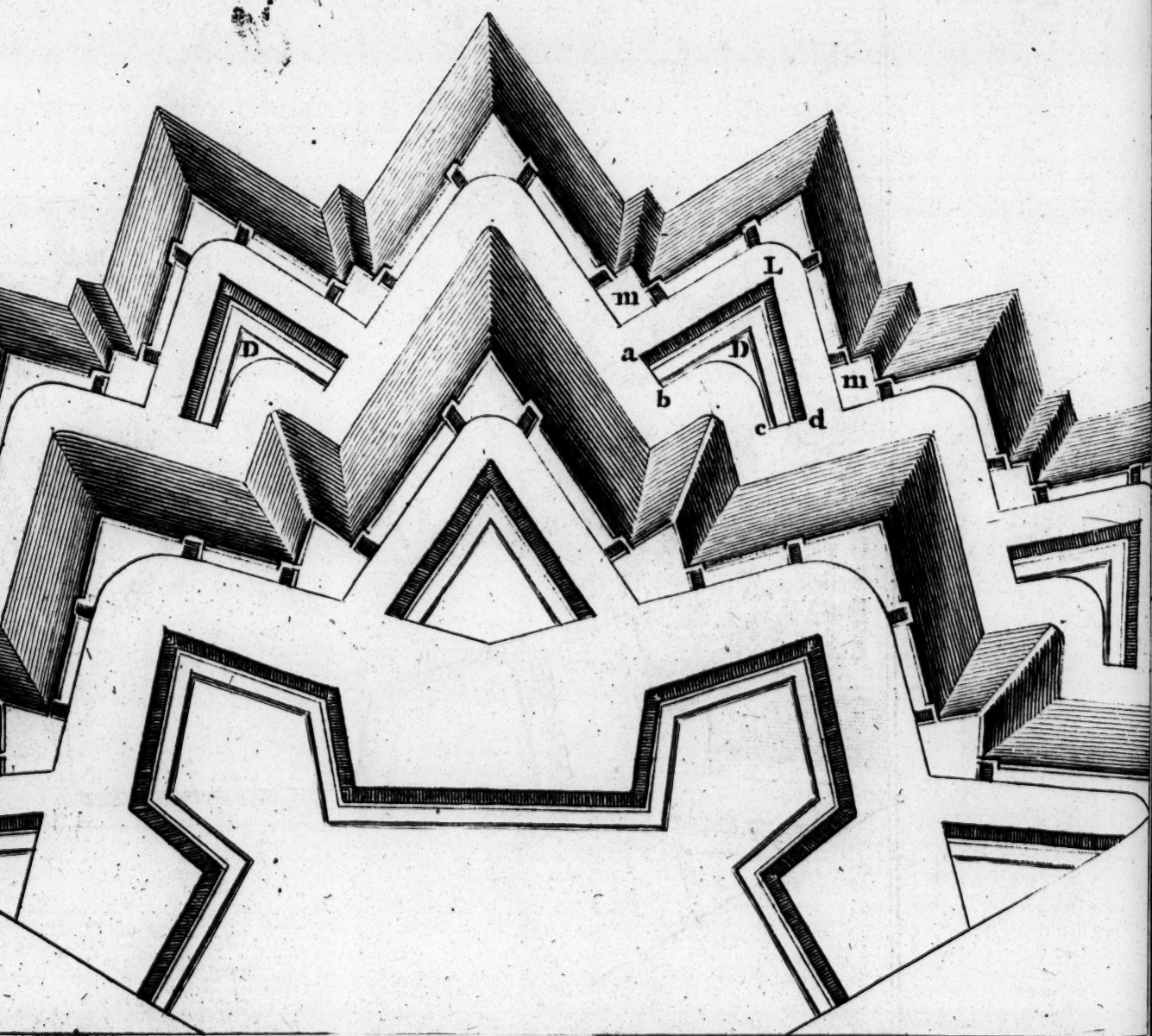
The gorge *ab* is 40 toises, the flanks *ac*, *bf*, which are perpendicular to the gorge, 10, and the faces *cd*, *fd*, 30; the ditch before it is 6 toises, ending in slopes at both ends; the covert-way 4; the branches of the covert-way are 42 toises long, or thereabouts; the faces of the places of arms *y*, *y*, which are perpendicular to the branches, 10; and the other, which is parallel to them, 14.

The communication from the covert-way into the redoubt, is 5 or 6 toises wide; and there is a traverse made just at the entrance; and another in the middle, when it is pretty long. The parapets of this communication terminate in a slope or glacis.

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If these redoubts are above 50 toises distant from the covert-way, the besiegers carry their trenches round, and enter through the gorge; by which the troops that are in them are made prisoners of war, if they do not retire betimes: to prevent this, some other outworks should be made to support them.

Construction of second Ditches, and Covert-ways.

When the ground is low, and water to be found, there is often a ditch of about 10 or 12 toises made round the glacis; and opposite to the places of arms are constructed lunettes, beyond the ditch, such as D, whose breadth on the counterscarp of the ditch is 10 toises, from b to a, and from c to d, and the faces aL, dL, are parallel to those of the places of arms; the ditch before them is from 8 to 10 toises wide. Plate VI.

The second covert-way is 4 toises, the semi-gorges of the places of arms m about 15, and the faces perpendicular to the counterscarp; the second glacis is from 15 to 18 toises broad.

This second covert-way has traverses every where, in the same manner as the first.

These

These are nearly all the different outworks, which are used now-a-days, in the construction of places : although they are generally ranked among M. *Vauban's* works, yet none are of his invention, except the construction of the body of the place, and the circular flanks ; for all the rest are to be met with in *Dilichin's Peribologia*, printed at *Frankford* in 1640 : and it may be observed, that M. *Vauban* has chiefly copied this author, as *Coehorn* did *Spekel*.

Construction of Profiles.

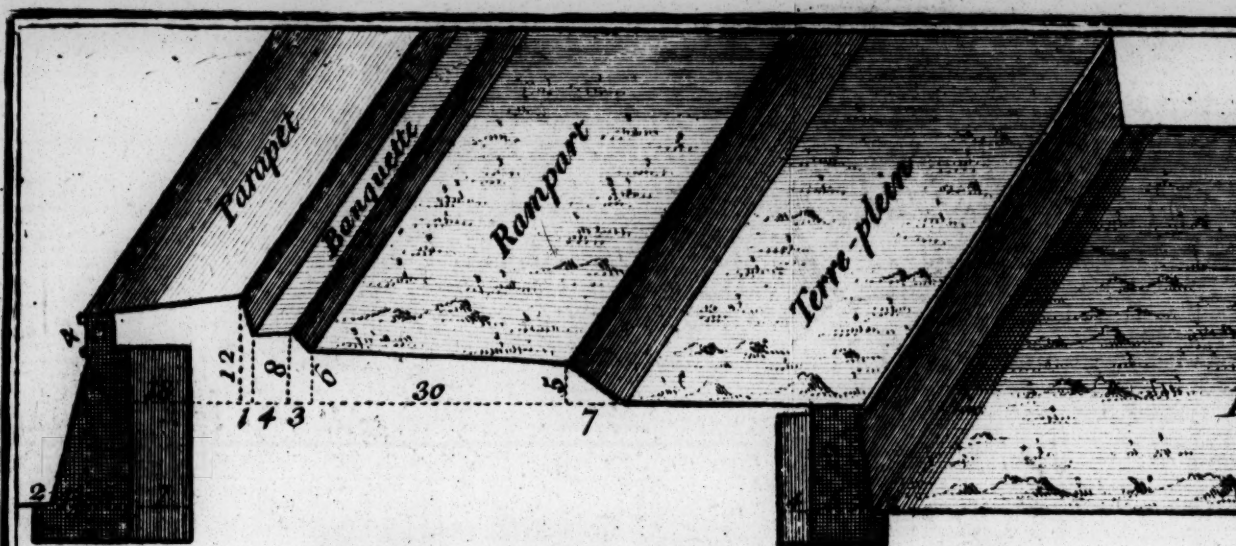
Plate VII. A profile is the representation of a vertical section of a work ; it serves to shew those dimensions which cannot be represented in plans, and are necessary in the building of a fortification ; they are generally constructed upon a scale of 30 feet to an inch. It would be needless to describe all their particular dimensions, since they are marked in the schemes ; we shall therefore lay down the principal rules only, given by M. *Vauban*, on this subject.

1. Every work ought to be at least 6 feet higher than that before it, so that it may command those before it ; that is, that the
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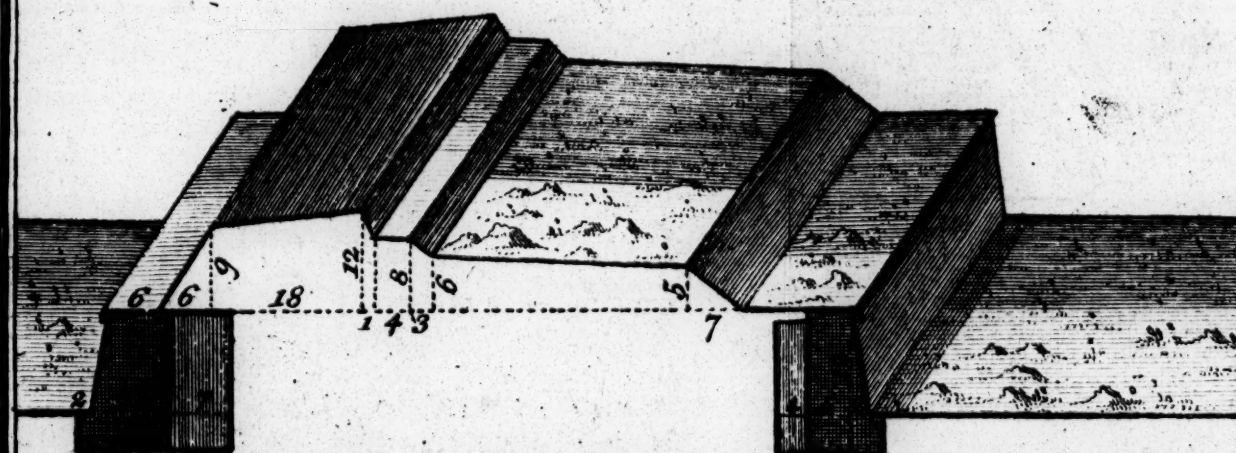
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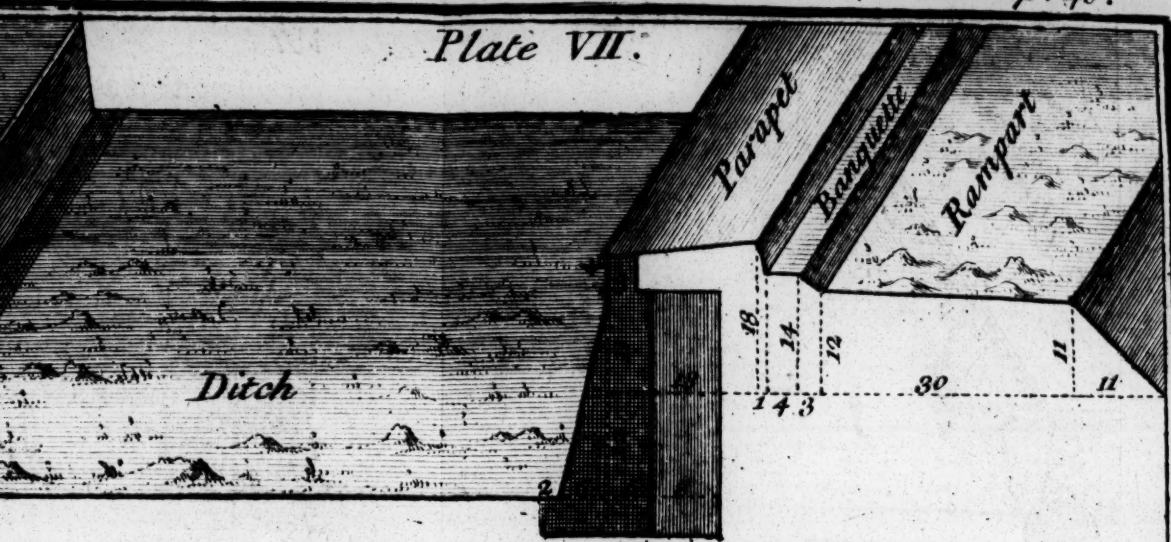
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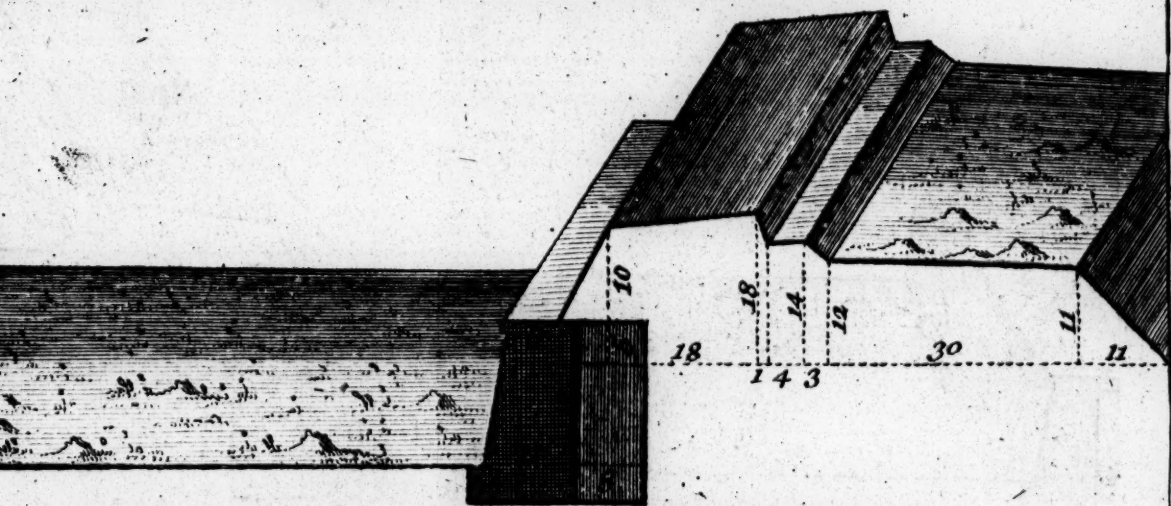
Profil of the Body of the Place and the



Plate VII.

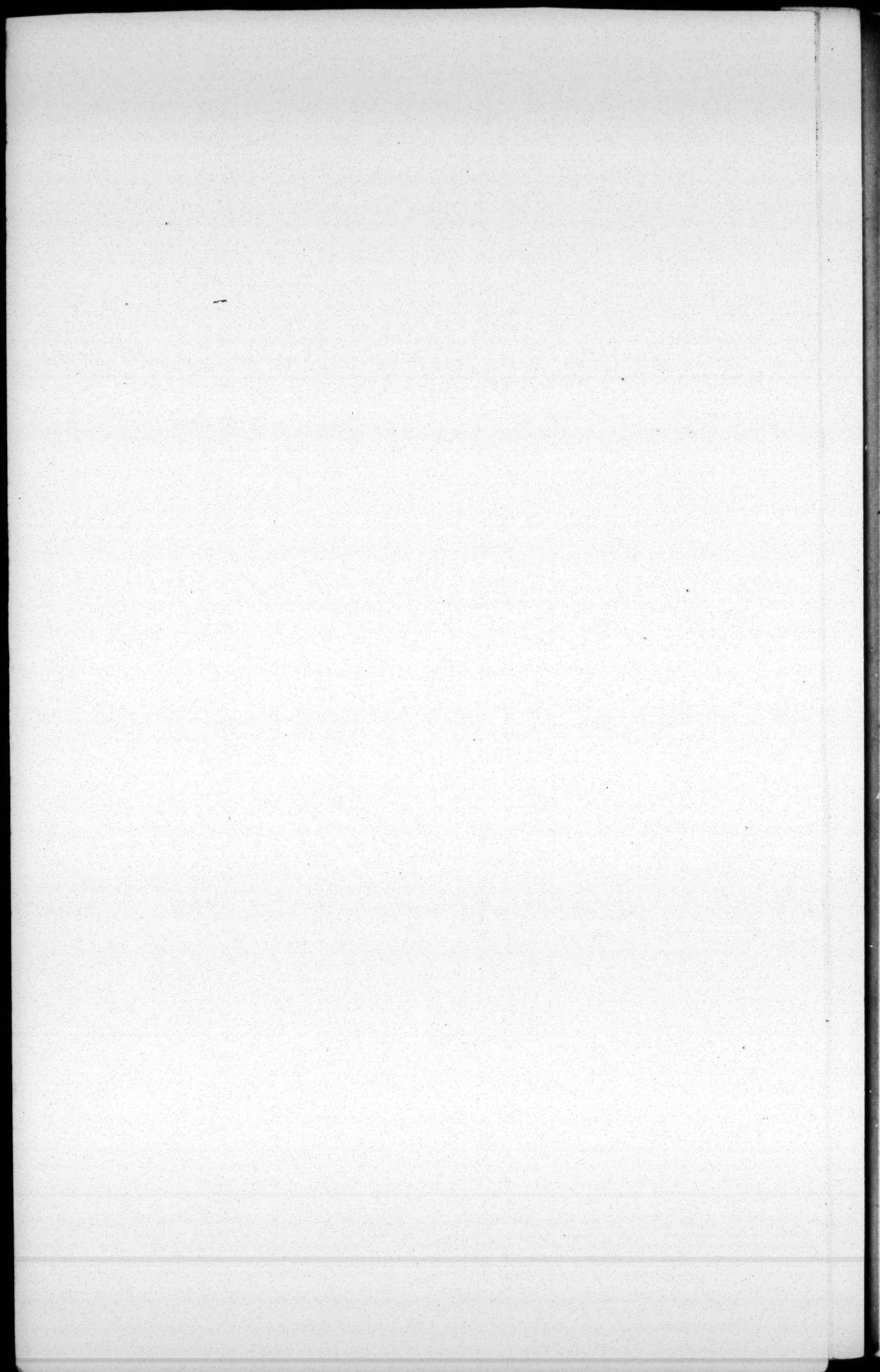


and the Ravelin with Revetement.



and the Ravelin with demi-Revetement.





garrison may fire from all the works at the same time, with great and small arms, at the besiegers in their approaches: notwithstanding this specious pretence, there are several authors, who object against it. For they say, if you can discover the enemy from all the works, they can discover by the same reason all the works from their batteries; so that they may destroy them, without being obliged to change their situation, and thereby dismount all the guns of the place before they come near it.

But if all the works were of the same height, those within cannot be destroyed, till such time that those before them are taken; guns might be placed in the covert-way and outworks to obstruct the enemy's approach, and when they come near the place, they might be transported into the inner works; and as the body of the place would be much lower, the expence would be considerably diminished.

But when works are lower, they are easily enfiladed by the ricochet batteries, which is a kind of firing, with a small quantity of powder, by giving the gun an elevation of 10 or 12 degrees: this might, however, be partly prevented, by making the parapets
near

near the salient angles, for the space of 8 toises on each side, five or six feet higher than the rest of the works.

2. The covert-way should be lower than the level ground, otherwise the body of the place must be raised very high, especially when there are several outworks; this is to be understood only when the works exceed each other in height, otherwise it need not be below the level.

3. The bases of all inward slopes of earth should be at least equal to the height, if not more.

4. The bases of all outward slopes of earth two thirds of their heights.

5. The slopes of all walls or revetements should be one fifth of their height; but one sixth would be sufficient in my opinion; the height of a wall is estimated from the bottom of the ditch, and not from the beginning of its foundation.

6. The slopes of all parapets and traverses are one sixth of their breadth; that is, 3 feet towards the field, or the inside, where the banquettes should be, three feet higher than the outside.

7. When the revetement of a rampart goes quite up to the top, 4 feet of the upper part
is

is a vertical wall of three feet thick, with a square stone at the top of it, projecting six inches, and a circular one below, or where the slope begins, of 8 or 10 inches diameter; they go quite round the rampart, and the circular projection is called the *Cordon*.

Where the straight part of the wall ends, and the slope begins, the wall is always made five feet thick; and the counterforts or buttresses reach no higher than that place.

8. When the rampart is partly walled and partly turfed, then one fifth of the height which is turfed must be added to five feet, to get the thickness of the wall above.

And having the thickness of any wall above, by adding one fifth of its height from the bottom of the ditch, the sum will be the thickness of the wall at the bottom; but if a sixth part is only taken for the slope, then a sixth part must be added.

For instance, suppose a rampart of 30 feet high from the bottom of the ditch, and that 10 of which are to be turfed; then the fifth part of 10, which is 2, added to 5, gives 7 for the wall above; and as this wall is 20 feet high, the fifth of which is 4, and 4 added to the thickness 7 above, gives 11 for the thickness near the foundation.

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THE ELEMENTS

The seventh plate represents in military perspective the profiles of the body of a place, the ravelin and covert-way, which gives a clear idea of what is meant by a profile; and from which those of all other works may be easily conceived.

M. *Vauban* gives in the following table the dimensions of walls from 10 to 80 feet high, from 10 to 10 feet.

Height of the wall.	Thick-ness above.	Thick-ness below.	Distances between the centers of the counter-forts.	Distances between the centers of the counter-forts.	Length of the counter-forts.	Thick-ness near the wall.	Thick-ness at the other end.
10	5	7	18	15	4	3	2 : 0
20	5	9	18	15	6	4	2 : 8
30	5	11	18	15	8	5	3 : 4
40	5	13	18	15	10	6	4 : 0
50	5	15	18	15	12	7	4 : 8
60	5	17	18	15	14	8	5 : 4
70	5	19	18	15	16	9	6 : 0
80	5	21	18	15	18	10	6 : 8

All these numbers are feet, except in the last column, which are feet and inches. M. *Vauban* adds, that when the stone or brick-

brickwork is very good, the thickness of the wall above may be reduced to $4\frac{1}{2}$ feet or 4 only; but when it is bad, it may be increased to $5\frac{1}{2}$ feet, and sometimes more.

That the counterforts at the saliant angles should be well braced or bound together.

When the ramparts are partly turfed and partly walled, he makes the intervals between the centers of the counterforts but 15 feet; but when they are walled quite up to the top, these distances are 18 feet.

These dimensions have been used in the constructions of a great many places, and the walls have never failed; it may however be demonstrated that his low walls are too strong, and the high ones too weak; but this subject shall be examined in the second book, where practical fortification is treated of.

As M. *Vauban* has constructed the foregoing tables from practice and his own observations only, and not by the help of theory, without which it is impossible to arrive to any degree of perfection; the dimensions contained therein are mostly erroneous, which indeed appears by mere inspection; for that all walls of any heights should have the same thickness at top, is contrary to sense and reason. Besides, he makes no distinction

between stone and brick walls, although stones are specifically heavier than bricks, and consequently need not be made so strong. For which reason we have inserted tables for stone and brick walls in the second volume of this work, which treats of the practice of fortification, deduced from theory and the most approved practice.

Construction of M. Vauban's second method, with Tower-bastions, according to the plans of Landau and Befford.

This method is adapted to the fortifying of places built already ; for which reason he begins his construction inwards, and fortifies outwards, contrary to his other methods, as being more convenient for that purpose.

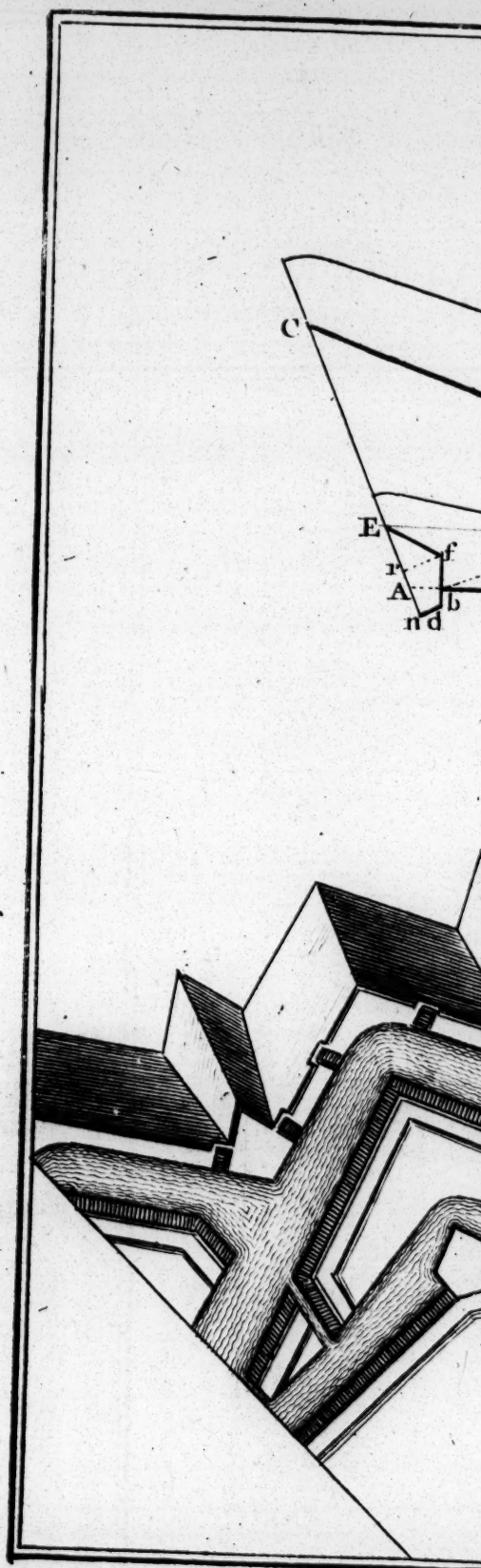
Plat.VIII. Let AB be the interior side of an exagon of 120 toises, some authors will have it 130, and say that they are so at *Landau* ; draw AC, BD, from the center through the extremities of the sides : set off 6 toises from A to b, and from B to c ; through the points b and c, draw lines at right angles to AB ; from the point b set off 6 toises to f outwards, and 4 from b to d inwards ; and from the
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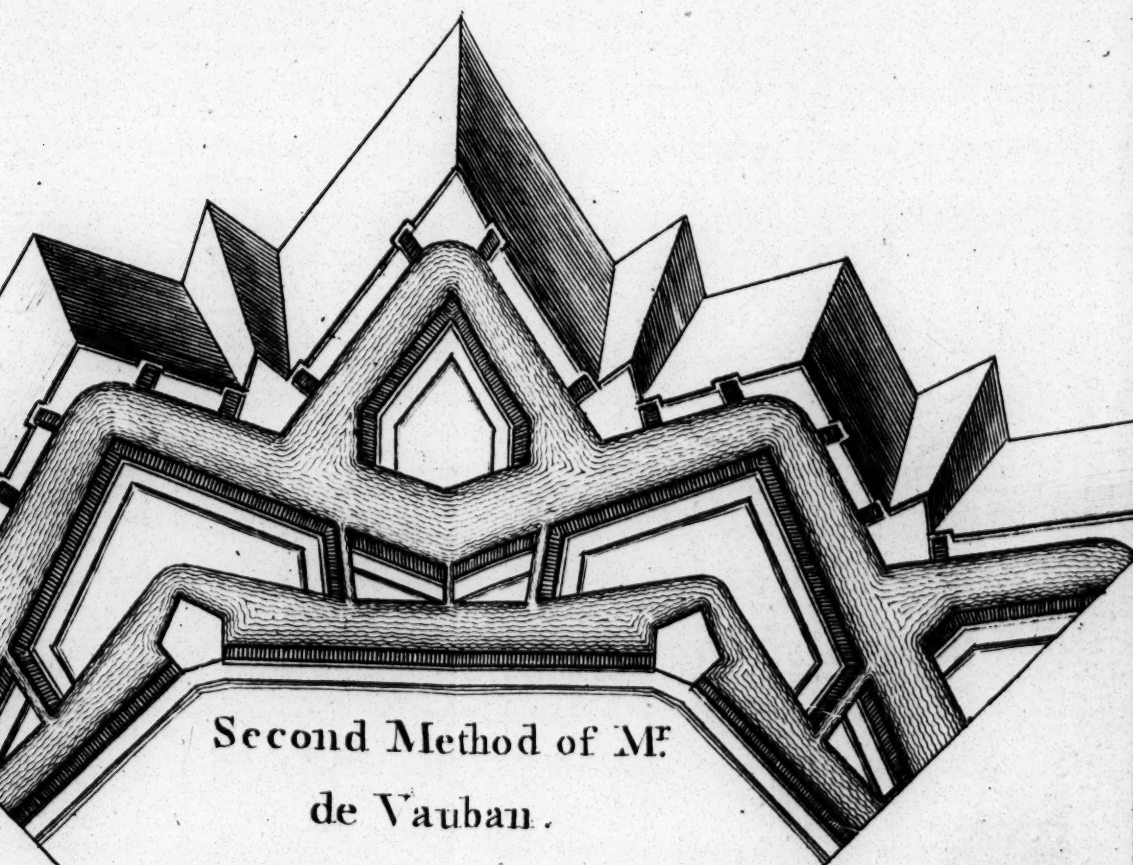
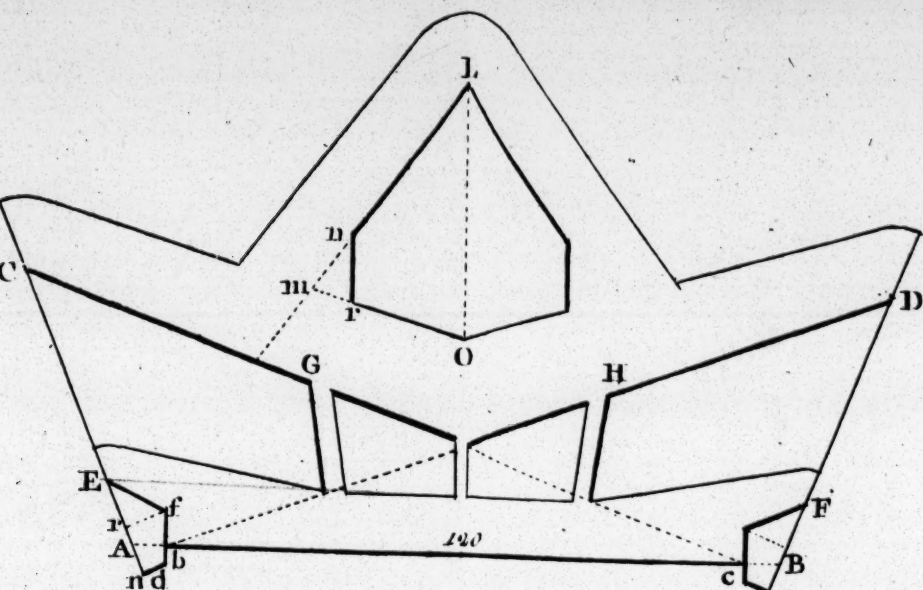
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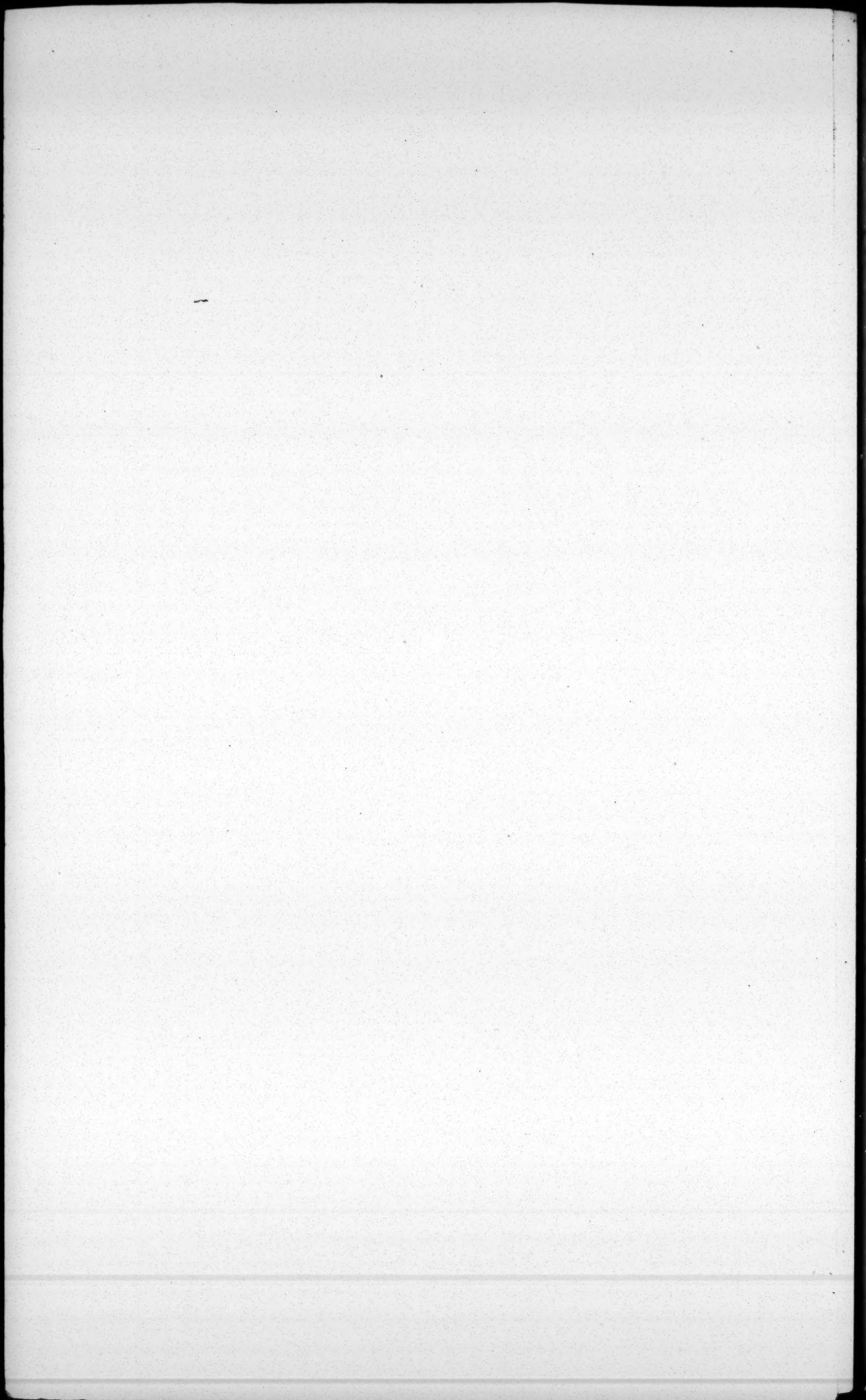
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points f, d , draw perpendiculars fr, dn , to the capital AC ; then if rE is made equal to rf , the point E will be the saliant angle of the tower-bastion; and $Efdn$ half that tower.

If in the capitals, there be taken from the saliant angles of the tower-bastions, the distances EC, FD , each of 40 toises, the points C and D will be the saliant angles of the counterguards before the towers: from the points C and D draw the lines of defence Cc, Db , to the points where the flanks of the towers cut the curtain; on which set off 56 toises for the faces of the counterguards, the flanks are found as in the first method, and likewise the tenailles.

The ditch before the saliant angles of the towers is 6 toises, and its counterscarp drawn to the extremities of the flanks of the counterguards; the right line which joins the ends of these flanks will determine the inside of the tenailles.

The ditch before the counterguards is 12 toises at the saliant angles, and the counterscarp is drawn to the opposite shoulders in the same manner as in the first method.

The capital of the ravelin is 45 toises, its faces, when produced, terminate on those of the counterguards, within 10 toises of the

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shoulders; 10 toises are cut off from the faces by the flanks which are parallel to the capital as usual.

The ditch before the ravelin is 10 toises, the covert-way 5, the semi-gorges of the places of arms 12, the faces 17, and the glacis 20.

Construction of M. Vauban's third method, according to the plan of New-Brifach.

Plate IX. This method is applied to an octagon, whose exterior side AB is 180 toises, the perpendicular CD 30; the faces AK, BL of the counterscarps 60: the flanks LN, KM are found by setting off 22 toises, as chords to the arcs described from the opposite shoulders as centers: from the extremities of the flanks a line is drawn, which will be parallel to the exterior side AB, meeting the capitals AE, BF, of the counterscarps at G and H; this line terminates the inside of the tenaille, as likewise the salient angles G, H of the tower-bastions.

If EF be drawn parallel to GH, and at 9 toises distant from it, the intersections E, F, with the capitals of the counterscarps, will
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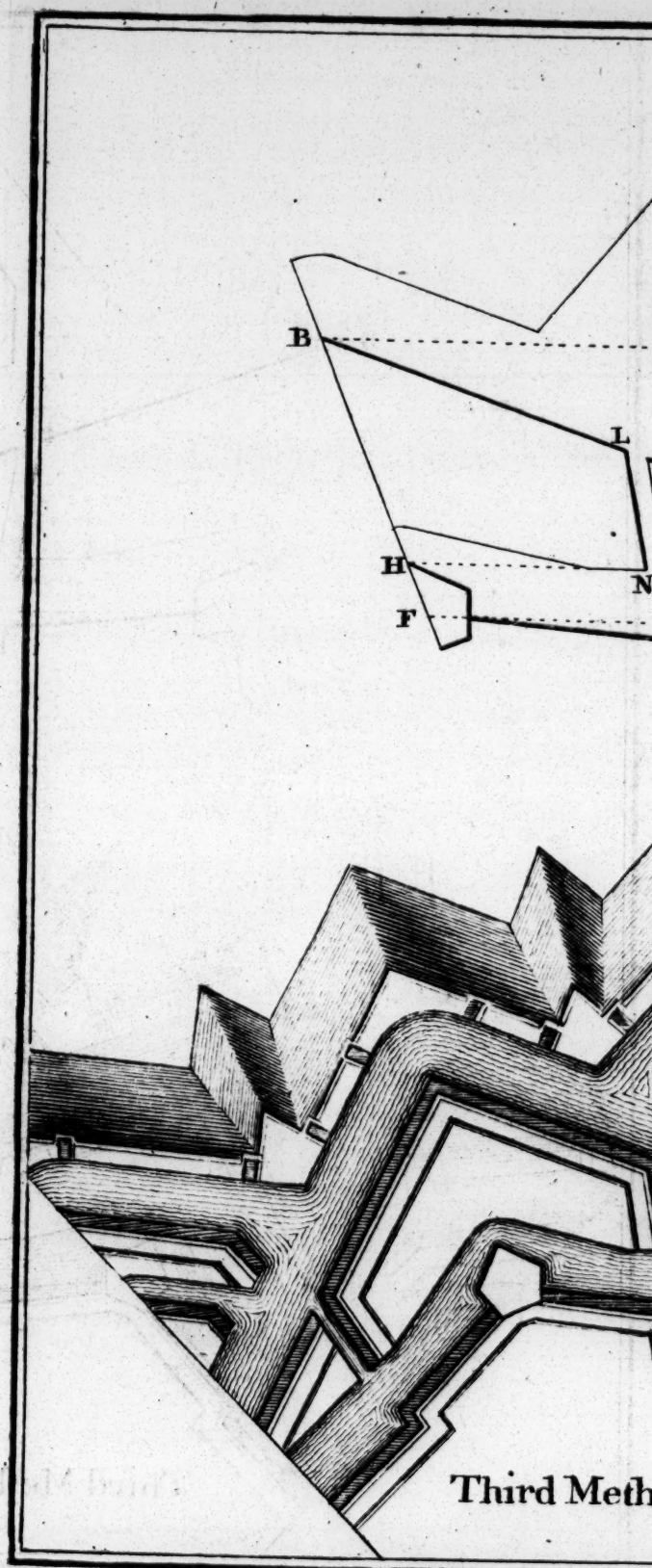
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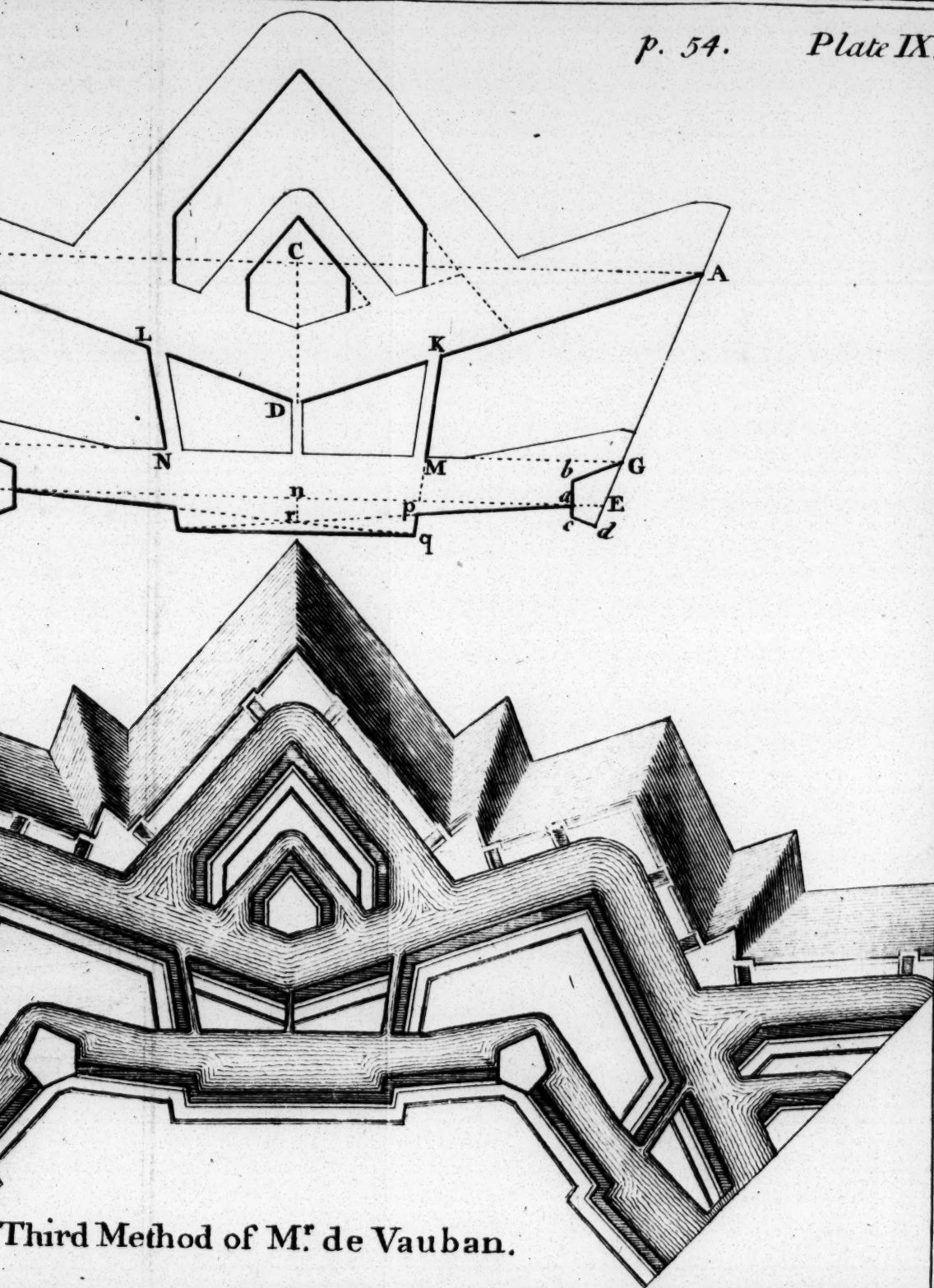
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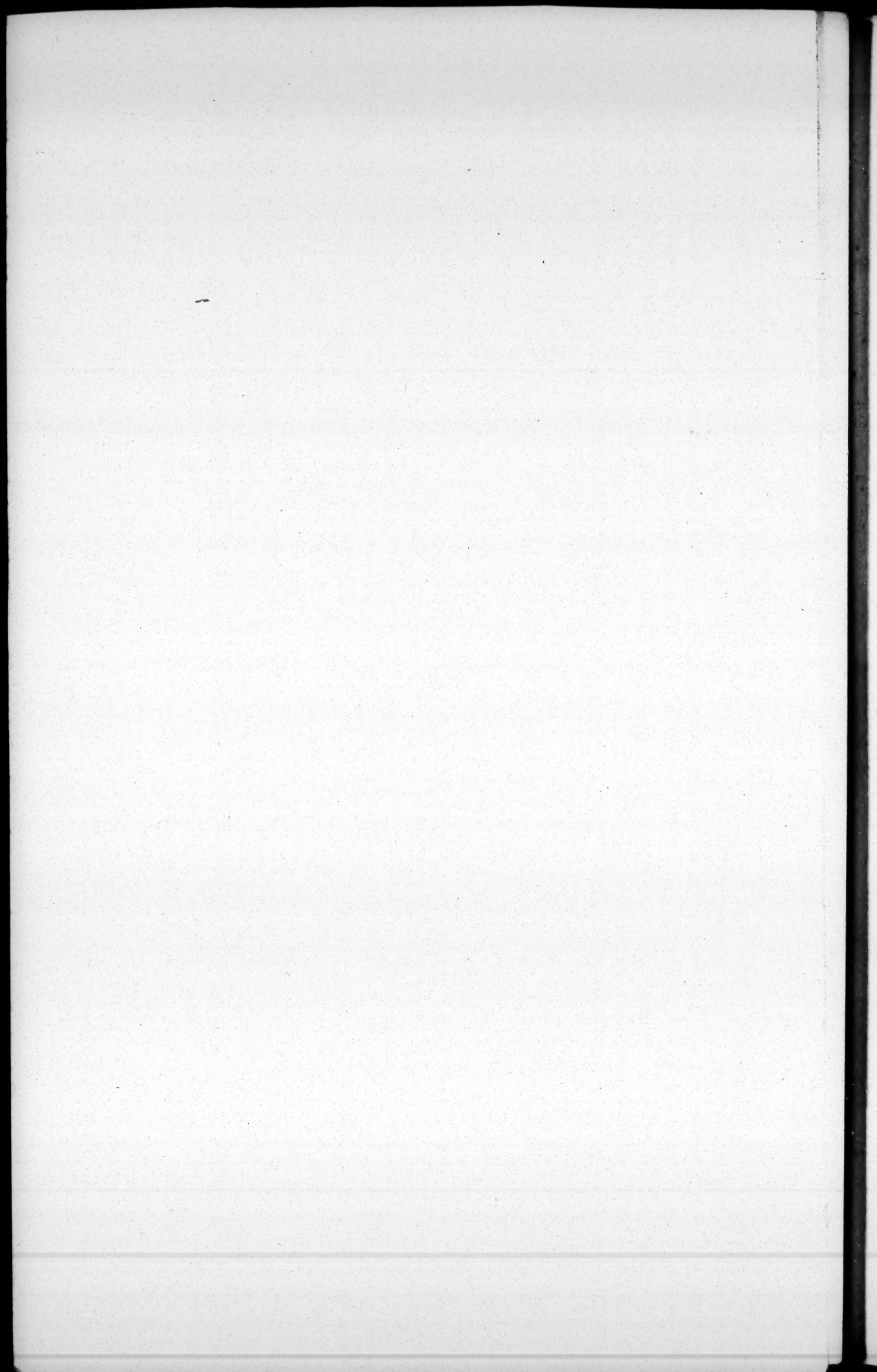
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Third Method of M^r de Vauban.



be the centers of the towers; from which set off 7 toises from E to *a* for the semi-gorges, and draw the flanks *b c* through the extremities of these semi-gorges perpendicular to the line EF; these flanks are 4 toises inwards from *a* to *c*, and 5 outwards from *a* to *b*; the faces *b G* are drawn from the point *b* to the point *G*, and the lines joining the inside of the flanks at the end of 4 toises will complete the towers.

The ditch is 6 toises before the saliant angle of the towers, and its counterscarp meets the line GH, within 10 toises of the extremities M, N of the flanks of the counterscarps.

If from the point *n*, where the line EF intersects the perpendicular CD produced, you set off 5 toises to the point *r*, and the lines of defence are drawn from the extremities of the semi-gorges *a* of the towers through this point *r*; then the flanks of the counterscarps produced will determine the little flanks *p, q* of the inside rampart, and the extremities of these little flanks being joined, will give the curtain between them.

The great ditch before the counterscarps is 15 toises, and its counterscarp parallel to the faces: the capital of the ravelin is 55

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toises,

toises, and that of the redoubt within it 23 ; the faces of the ravelin are drawn to the faces of the countersguards within 15 toises from the shoulders, and those of the redoubt parallel to these : 12 toises are cut off from the faces of the ravelin, and 6 from those of the redoubt, by the flanks which are parallel to the capital ; the ditch before the ravelin is 12 toises, and that before the redoubt 6 : the covert-way and glacis are the same as in the second method : the profiles in plate X, XI, referred to this method, may serve likewise for the second. It must be observed, that the parapets of the countersguards, on both sides of the salient angles, are raised 4 feet higher, for the space of 20 feet, above the rest, to prevent the enfilades of the ricochet batteries.

We shall examine these two last methods in the third section, in order to shew their perfections and imperfections.

Construction of M. Coehorn's first method.

Plate XII. This author applies his first method to an exagon, and supposes that the surface of the water is but 4 feet lower than the level ground. Let

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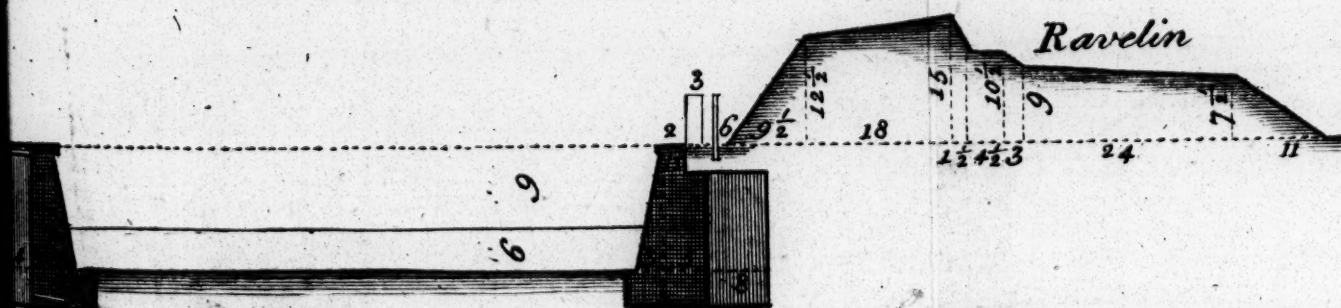
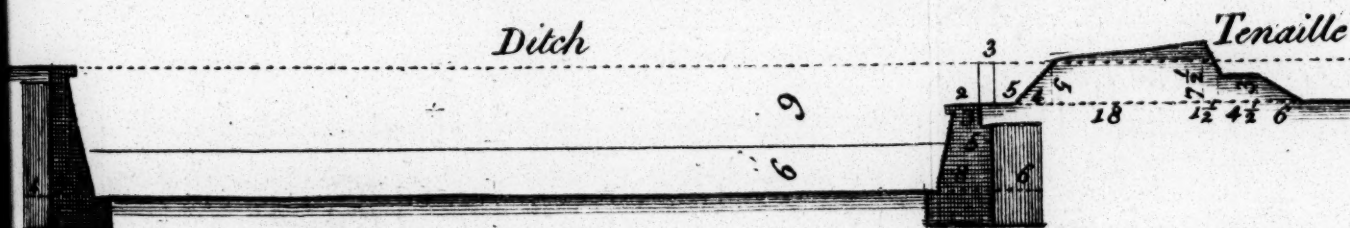
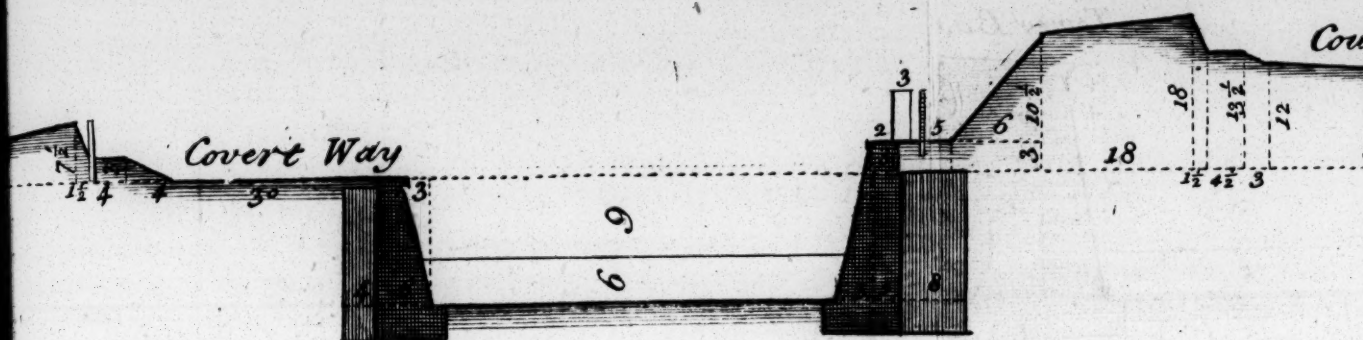
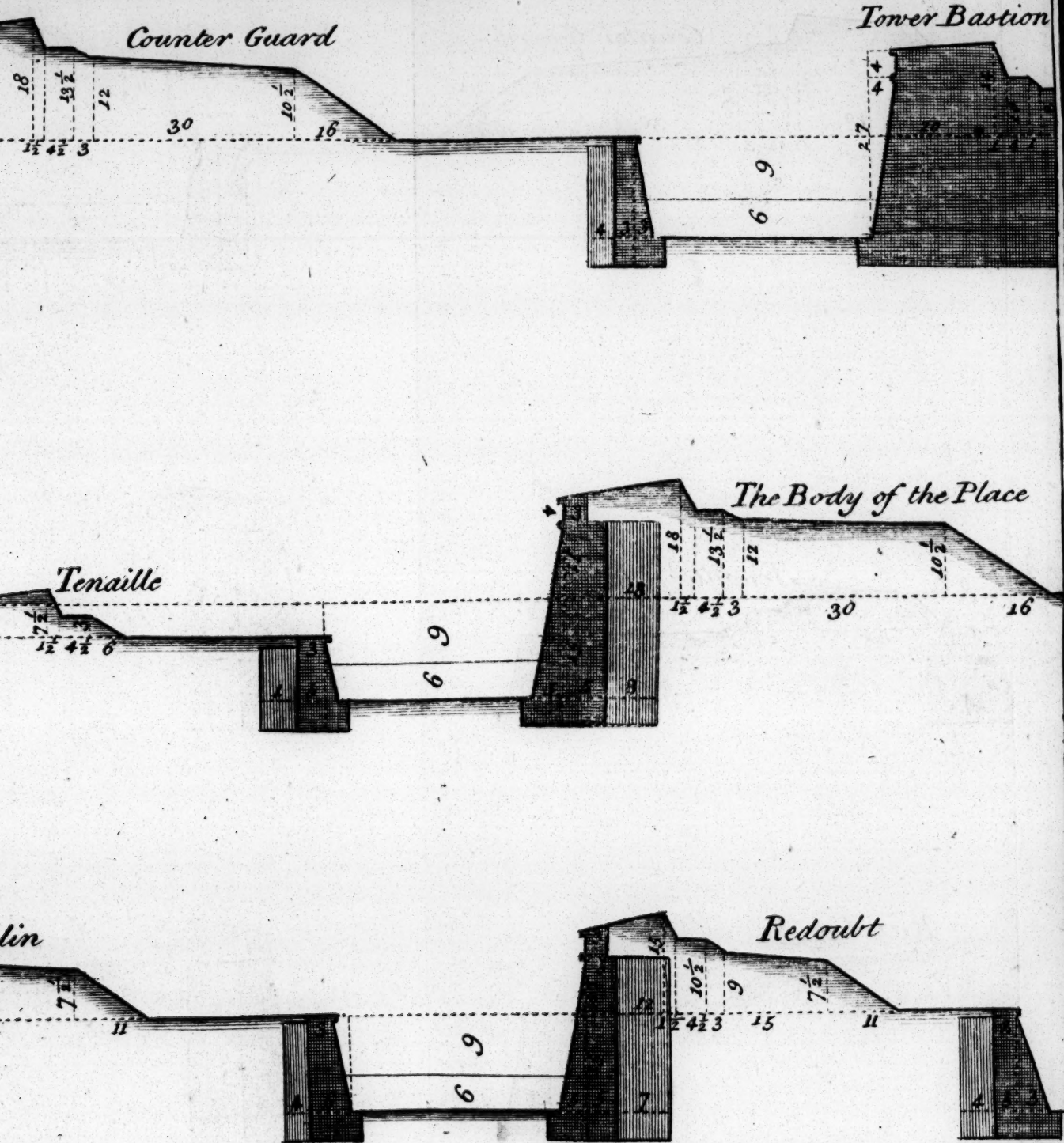
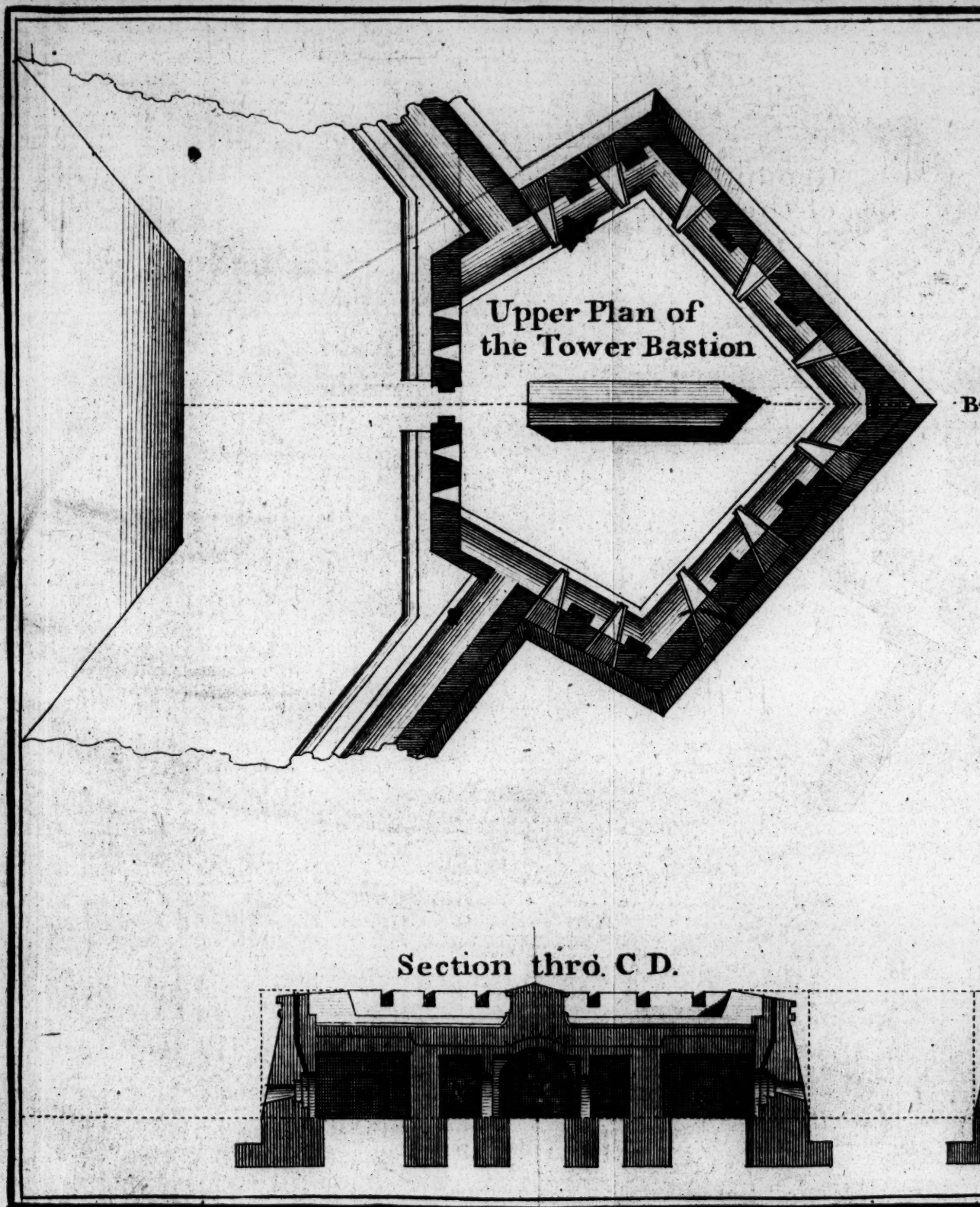


Plate X.

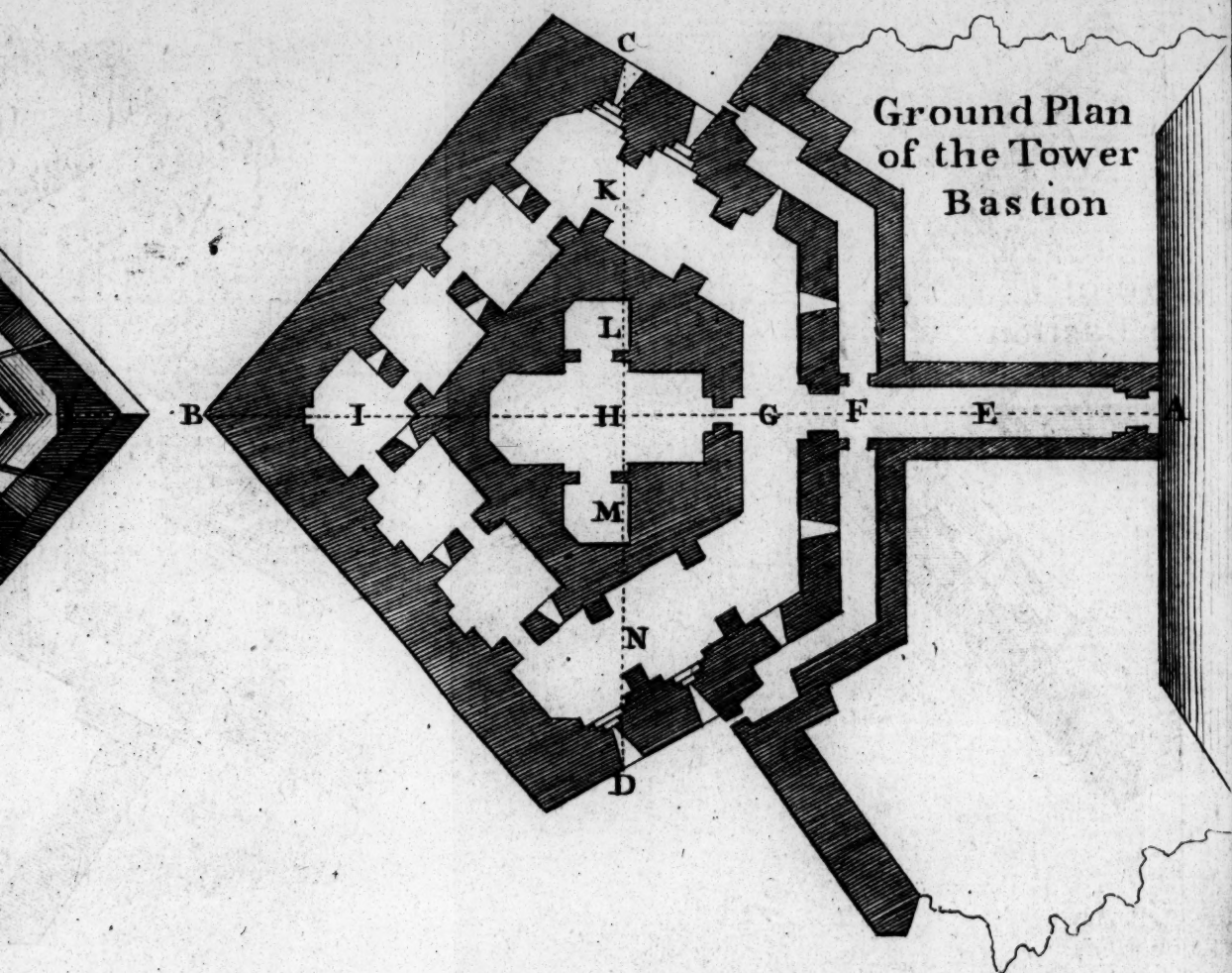
Vauban's third Method



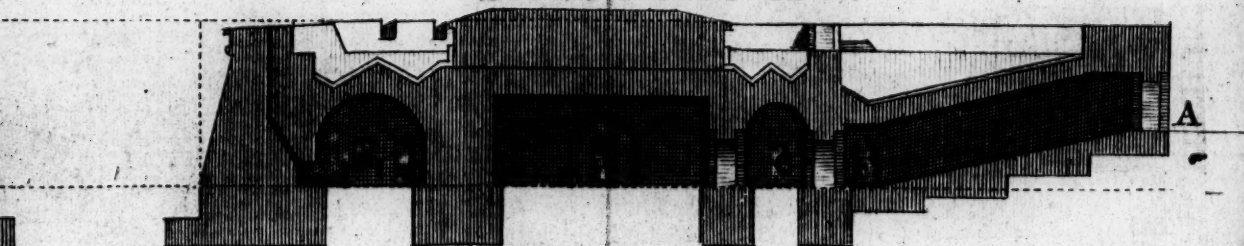


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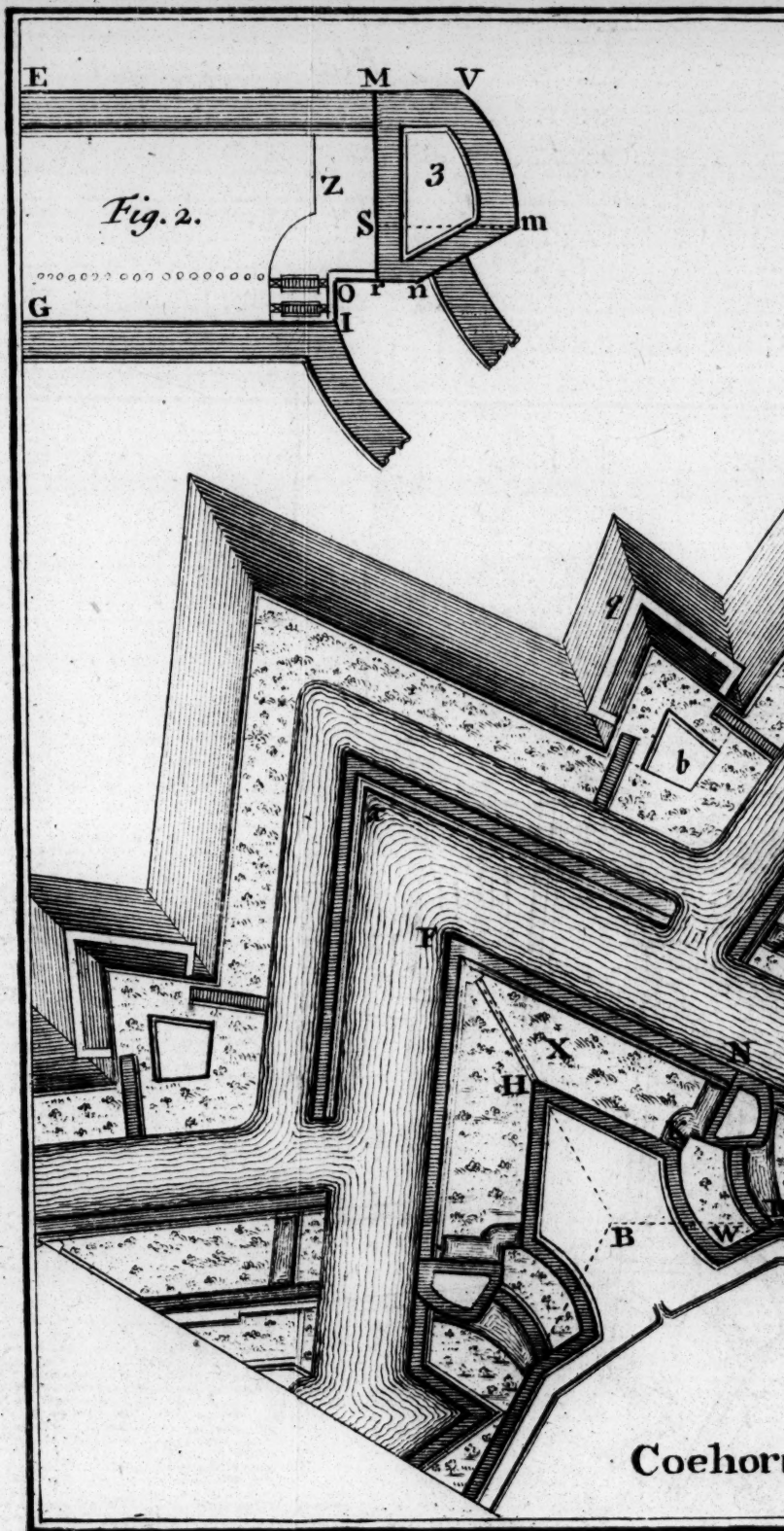
Plate XI.



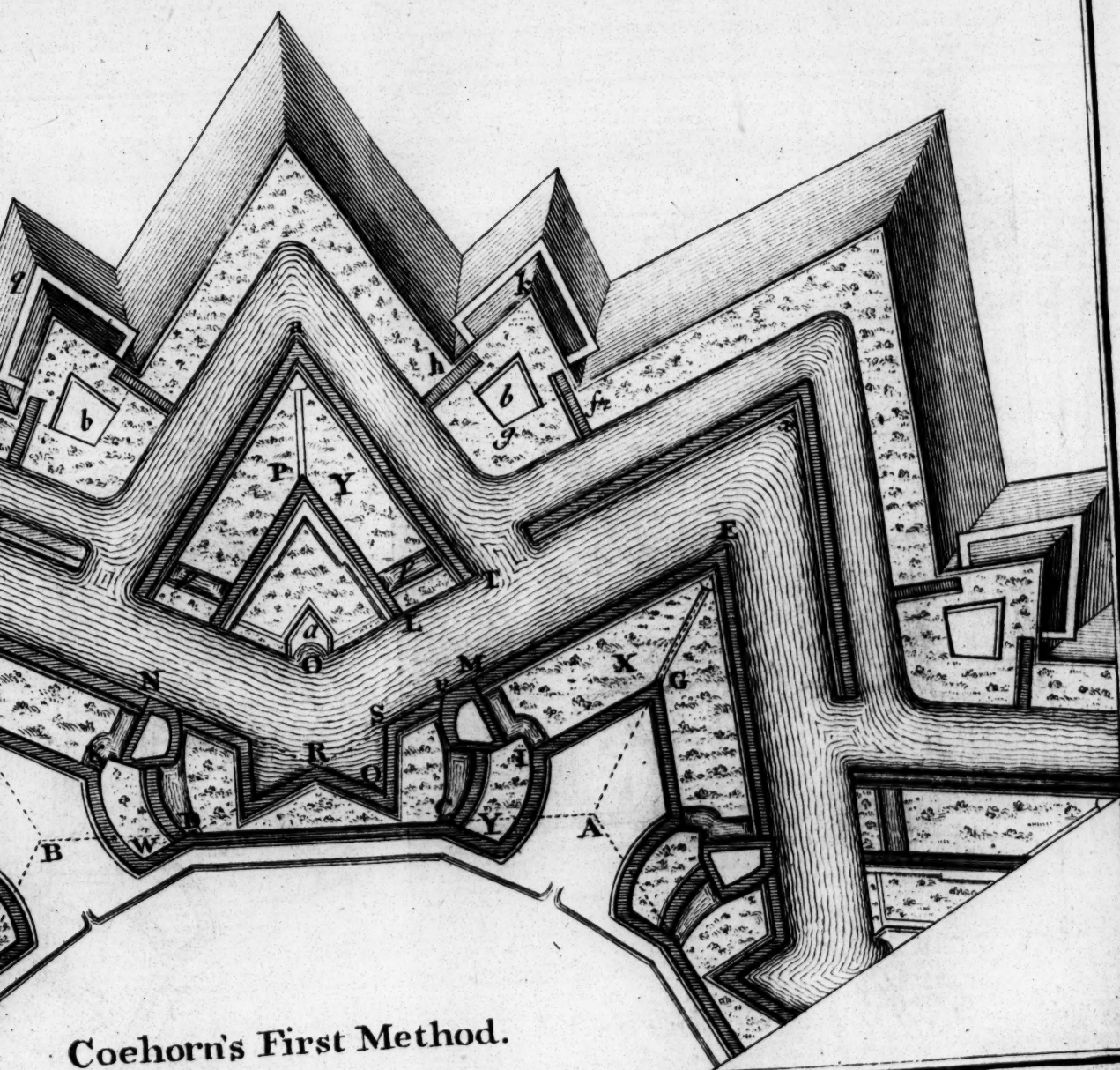
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J. Mynde sc.

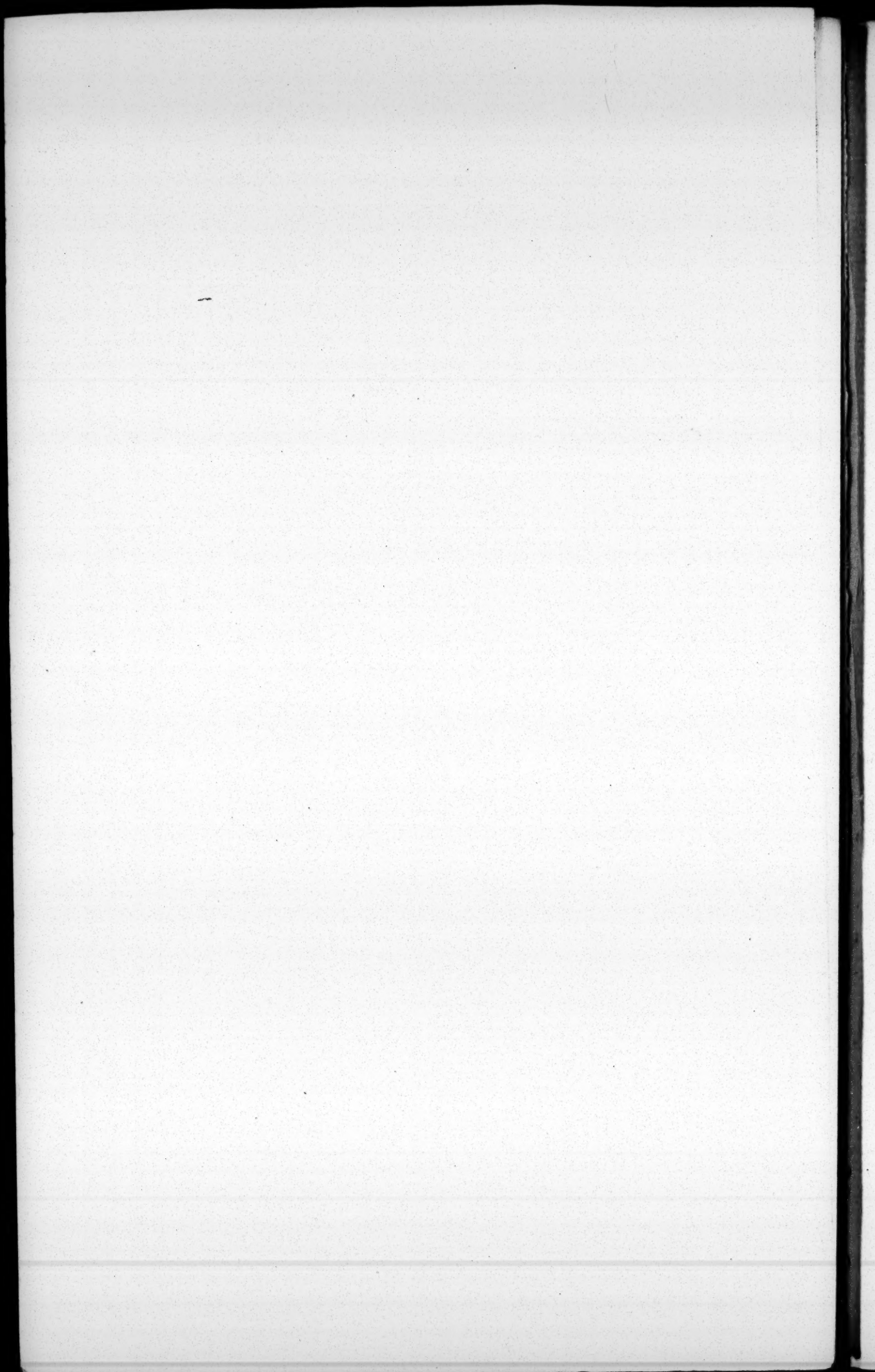


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Coehorn's First Method.

J. Myndesfc.



Let therefore the interior side AB of an exagon be 150 toises, take AC, BD, each equal to 39, and the capitals AE, BF, each of 80; and AG, BH, of 40; from the points E, F, draw the lines of defence through the points D, C; and through the points G, H, lines parallel to ED, FC; in which take GI, HK, each equal to 40 toises, for the length of the higher faces of the bastions.

To determine the lower faces EM, FN, Fig. 1. draw IO perpendicular to IG, equal to 4 toises; Or, parallel to IG, likewise equal to 4; then rM perpendicular to EM will determine the lower face EM.

In order to determine the tower 3, see fig. 2; in rM, take rS of 5 toises, draw Sm parallel to EM, and equal to 14; in Or produced, take likewise rn equal to 4, and in EM, MV to 8; then if the points n, m are joined by a right line, and m, V by an arc of 60 degrees, you will have the outline of the tower.

The lines IO and Or, express two walls, the first has two embrasures, and the second three; by which the author intended to defend the dry ditch, and the approach to the tower.

If

If from the points C, D, fig. 1, there be set off on the lines of defence 14 toises to the points Y, W; and upon each of the bases \overline{YI} , \overline{WK} be described an equilateral triangle, the angles opposite to these bases, will be the centers of the higher flanks YI, WK.

And if R be the intersection of the two lines of defence, RM dissected at S, and RC at Q; by drawing SQ, $\angle SQR$ will be half the tenaille; and drawing from the point C, a line parallel to IY, so as to meet the tower, upon which the mean flank is described in the same manner as the former.

Fig. 2. The parapets of the three flanks, and those of the parts mV, VM, of the towers, are 24 feet thick; the other parts Mr, rnm, but 16; and all the other parapets in general are 20 feet.

There is a wet ditch before the mean flank of 6 toises broad, and another z, behind the towers of the same breadth, over which are made two draw-bridges, parallel to the higher faces.

The space X between the higher and lower faces of the bastions in a dry ditch, whose bottom is but 6 inches above the surface of the water in a wet ditch.

Behind

OF FORTIFICATION.

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Behind the lower parapet there is a banquette of 3 feet, and a rampart of 5; and under this rampart a stone gallery, which runs from one end to the other, and is divided into several apartments, which are shut with doors; as likewise another, going from the saliant angle of the lower faces, to that of the higher, with loop-holes from distance to distance facing the dry ditch: there is likewise a row of palisades placed parallel to the higher faces, and at 4 toises distant from them.

There are three embrasures in O r, as has been said, to flank the ditch z behind the towers; and two in IO to flank the dry ditch near the higher faces.

The great ditch is 24 toises broad; and its counterscarp parallel to the lower faces of the bastions; the semi-gorges OL of the ravelin are 29 toises, and the faces LP, 45; the dry ditch Y is 16 toises, the rampart 28 feet, and the lower faces aT are parallel to the higher ones; the parapet of which is 20, and the banquette 3.

The level ground of the rampart in the ravelin near the saliant angle is 20 feet broad, for the length of 20 toises from that angle, and the rest but 15.

In

THE ELEMENTS

In the gorge of the ravelin is a small redoubt *a*, of about 5 feet high, and underneath a lodgment of stones, the walls being 18 inches thick at the sides; the roof is made of planks, with 3 feet of earth over them.

There is a dry ditch going from the extremities of the faces to the redoubt, and round its angle, having a row of palisades before it, to secure the retreat from the ravelin into this redoubt; there is likewise another row going from the extremities of the faces, in a round form, turning towards the gorge of the ravelin.

In the dry ditch of the ravelin, within 6 toises from the great ditch, is a coffer, and a ditch of 6 toises before it: this coffer has a wall on both sides, and the roof is planked and covered with a foot and half of earth; above this, is a stone parapet of 5 feet high, with a banquette behind it.

There runs a covered gallery under the rampart of the lower faces, and another joining the two salient angles, together with a row of palisades, in the same manner as in the dry ditch before the bastions.

The wet ditch before the ravelin is 18 toises; the counterscarps *x*, which the author calls *cover-faces*, are 25 feet broad, and the

the ditch before them 14 toises ; the covert-way is 12 toises broad, and the glacis 20 : the semi-gorges fg, gh, of the places of arms, are 22 toises, and are taken from the point g, where the branches of the covert-way meet, and the faces fk, hk, are 28 ; within these places of arms are traverses of 20 feet thick and 18 toises long, within 10 or 12 feet from, and parallel to the faces.

The stone lodgments b, within the places of arms, are found by setting off 12 toises from the point g, for the semi-gorges, and the faces are drawn parallel to those of the places of arms.

At 6 toises from the places of arms, are coffers q of 8 feet broad, made with planks at the sides, and above with a foot of earth over and before them.

There are two banquettes all round the covert-way, and before the traverses ; as also two rows of palisades before the traverses, one of which joins them, and the other goes round the covert-way.

Lastly, the re-entering angles of the counterescarp next to the covert-way are made a little round, as likewise that in the ravelin ; but the contrary way, that is, they are made hollow.

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Construction of M. Coehorn's second method.

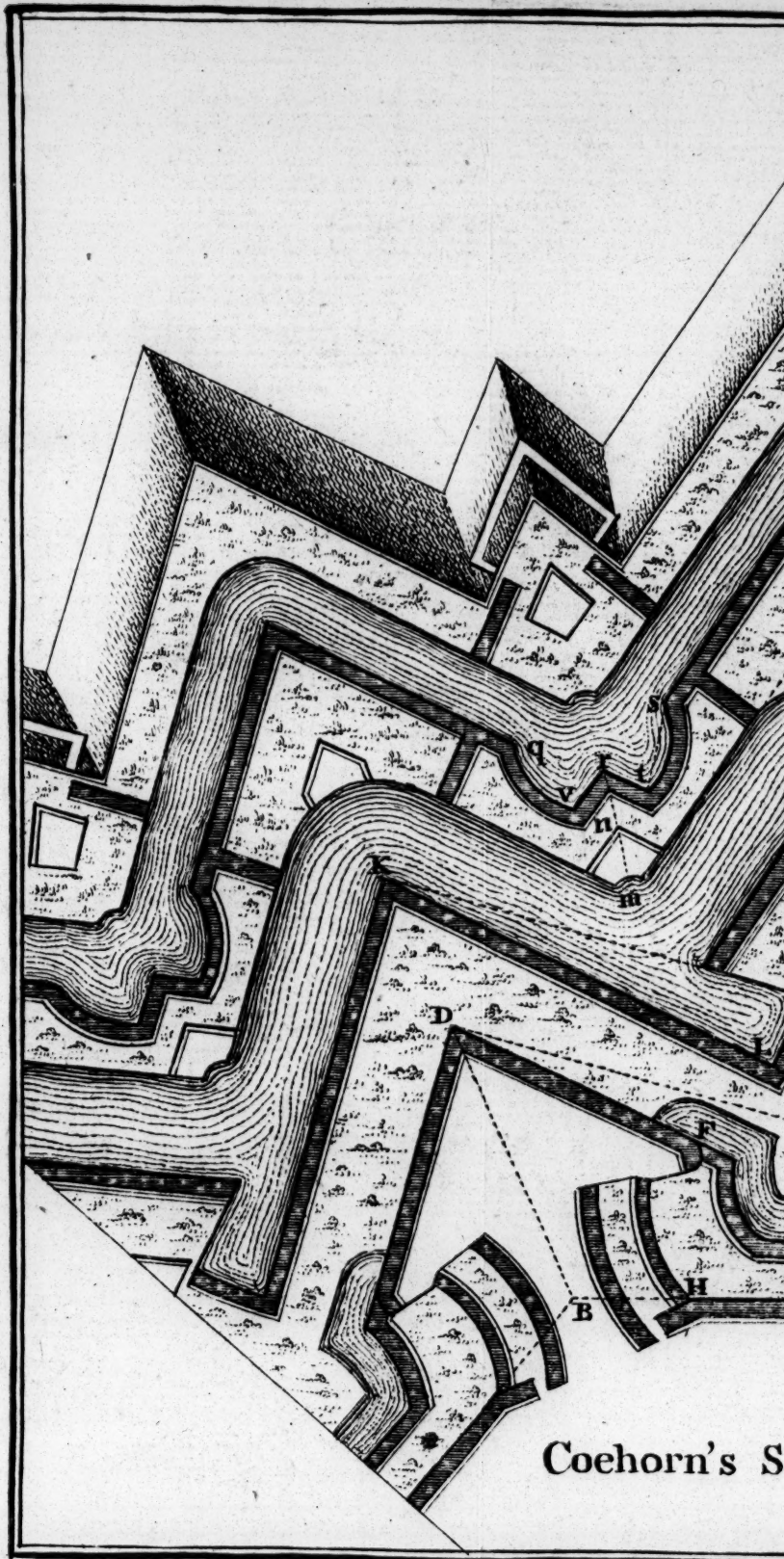
Pl. XIII. The author supposes an eptagon, whose interior side is 126 toises, and the level of the ground to be 3 feet above the surface of the water.

Let, therefore, the interior side AB of an eptagon be 126 toises, take in the capitals, AC, BD, each of 72 toises; at the extremities C, D, make the angles ACE, BDF, each of 40 degrees; and set off 66 toises for the faces CE, DF of the bastions; on the interior side, take AG, BH, each of 30 toises, and from the point D, as center, describe an arc through the point G, on which set off a chord of 30; and on this chord describe the mean flank GI, which is an arc of 60 degrees.

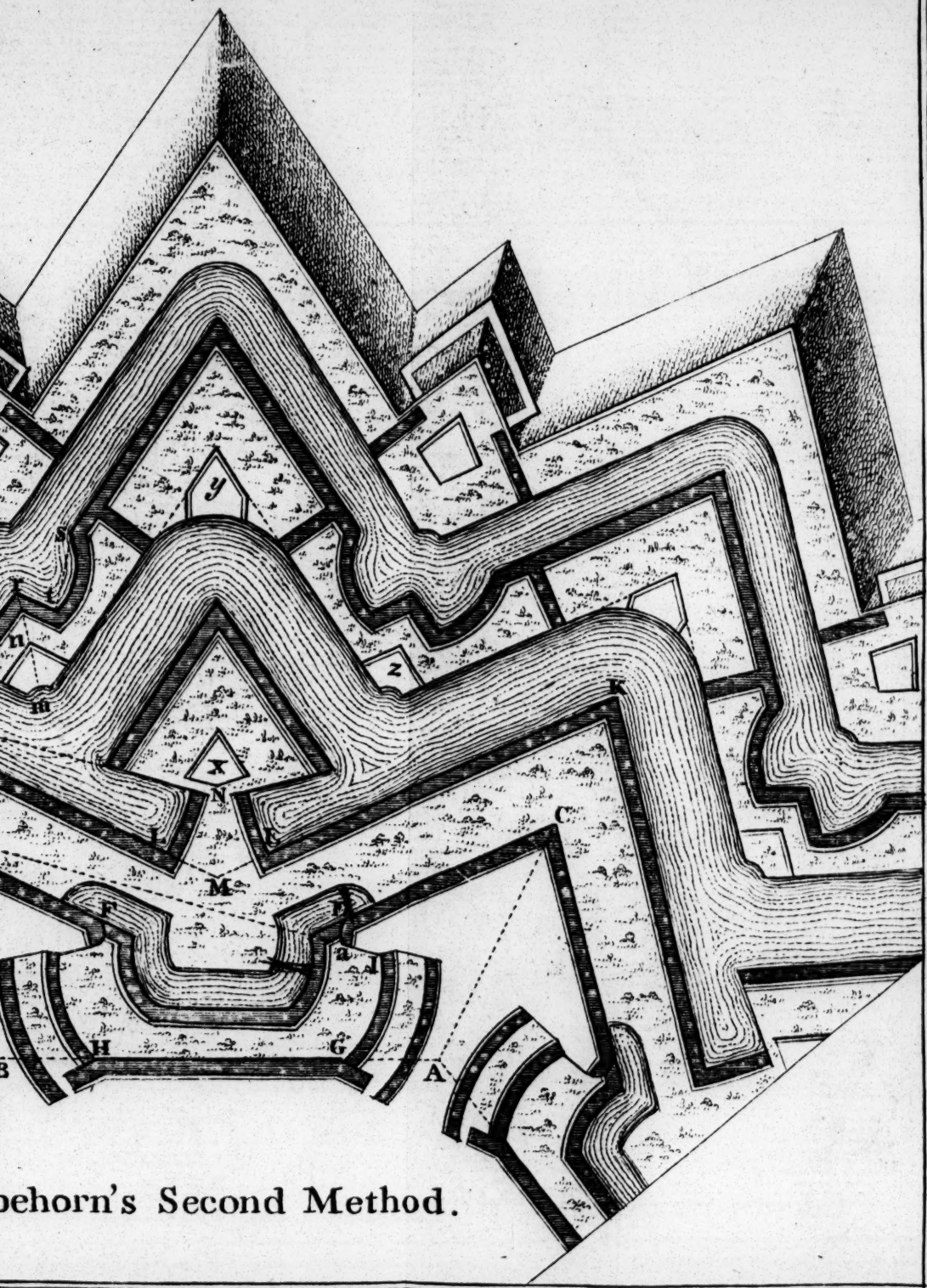
Draw a line from the salient angle D through the extremity I of this flank, on which take Ia of 10 toises; join a E, on which describe the orillon as usual.

The outline of the higher flank is 13 toises distant from that of the outline of the mean; this flank is an arc described from the arme center as that of the former, the chord of which is 40 toises.

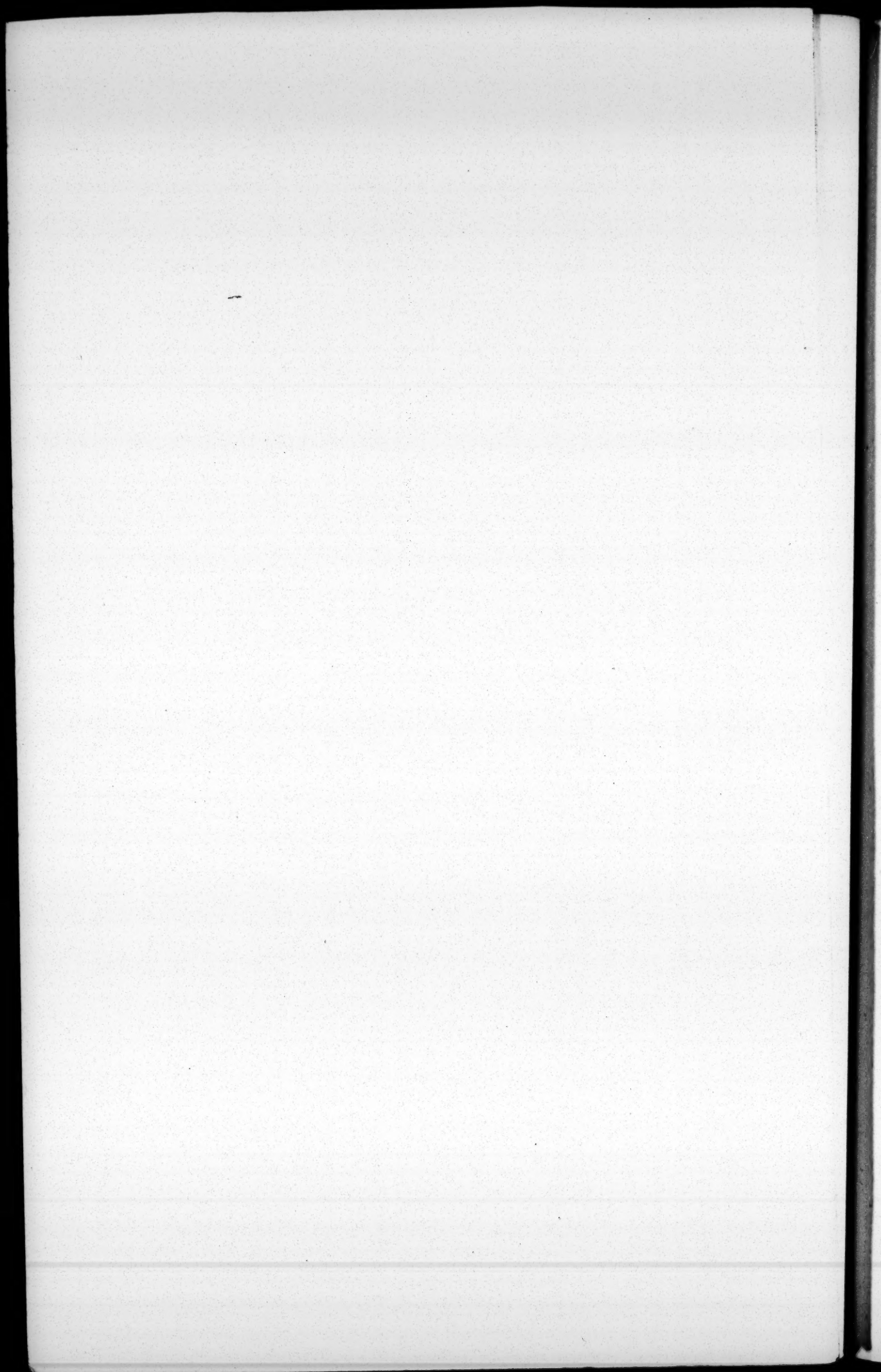
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Behorn's Second Method.



From the points G, H, draw the broken parts of the curtain perpendicular to the capital of the bastion, and make it 9 toises long; the extremity of the higher flank is terminated by the inside line of the parapet of the curtain produced.

The tenaille is found, by producing the faces of the bastions 10 toises; through the extremity of which, an arc is described from the opposite salient angle of the bastion, as center; on this arc is set off a chord of 20 toises; and this chord serves to describe the flank, upon which is an arc of 60 degrees; the curtain is a right line.

There is a wet ditch before the tenailles of 10 toises broad, with two bridges at each end, near the orillons; the one directly over it, and the other along the faces of the bastion.

The dry ditch round the body of the place is 20 toises broad, before the faces of the bastion to which it is parallel, and the lower rampart KL, 29 feet; the semi-gorges ML are 15 toises, and the flanks LN, 18, and are described from the salient angles K of the lower faces as centers.

The salient angle of the ravelin is 125 toises distant from the curtain of the body
6 of

of the place, and is 70 degrees; the faces are 50 toises long; the faces of the redoubt x, are 16 toises distant from those of the ravelin, and 14 long.

The wet ditch round the lower faces of the ravelin is 24 toises broad: the work beyond this ditch, which the author calls the second counterscarp, is 20, parallel to the ditch.

To find the broken part of this work, join the two re-entering angles m, r; on which take mr, of 30 toises, and draw rt, rv parallel to the outline of the counterscarp, each equal to 12: set off 22 from t to s, and from v to q; and upon these lines as chords describe the round flanks, which are arcs of 60 degrees.

The traverses in this counterscarp are drawn at 10 toises from the flanks perpendicular to the parapet.

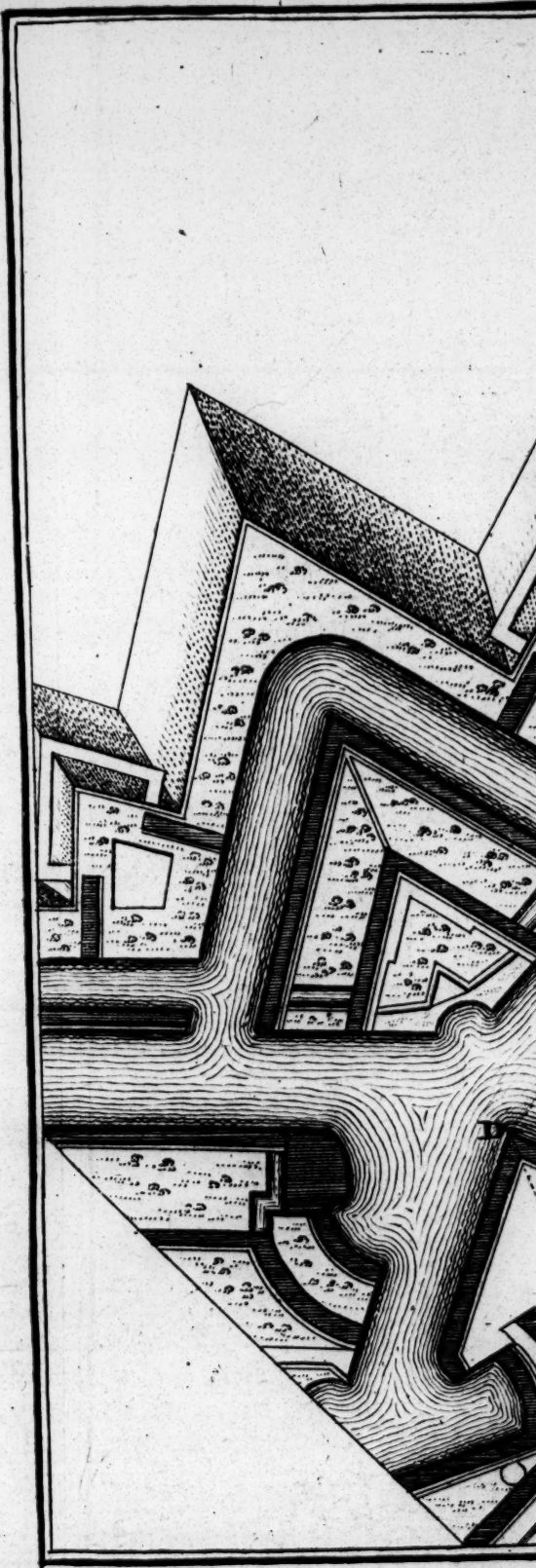
The redoubts z in the re-entring angles, are found by setting off 16 toises from the points m to n, for their capitals, and the faces are parallel to the broken curtain before them: those marked y, which are in the salient angles, are found by producing the counterscarps of the great ditch, and setting off 12 toises from the points of their intersections for their faces; and

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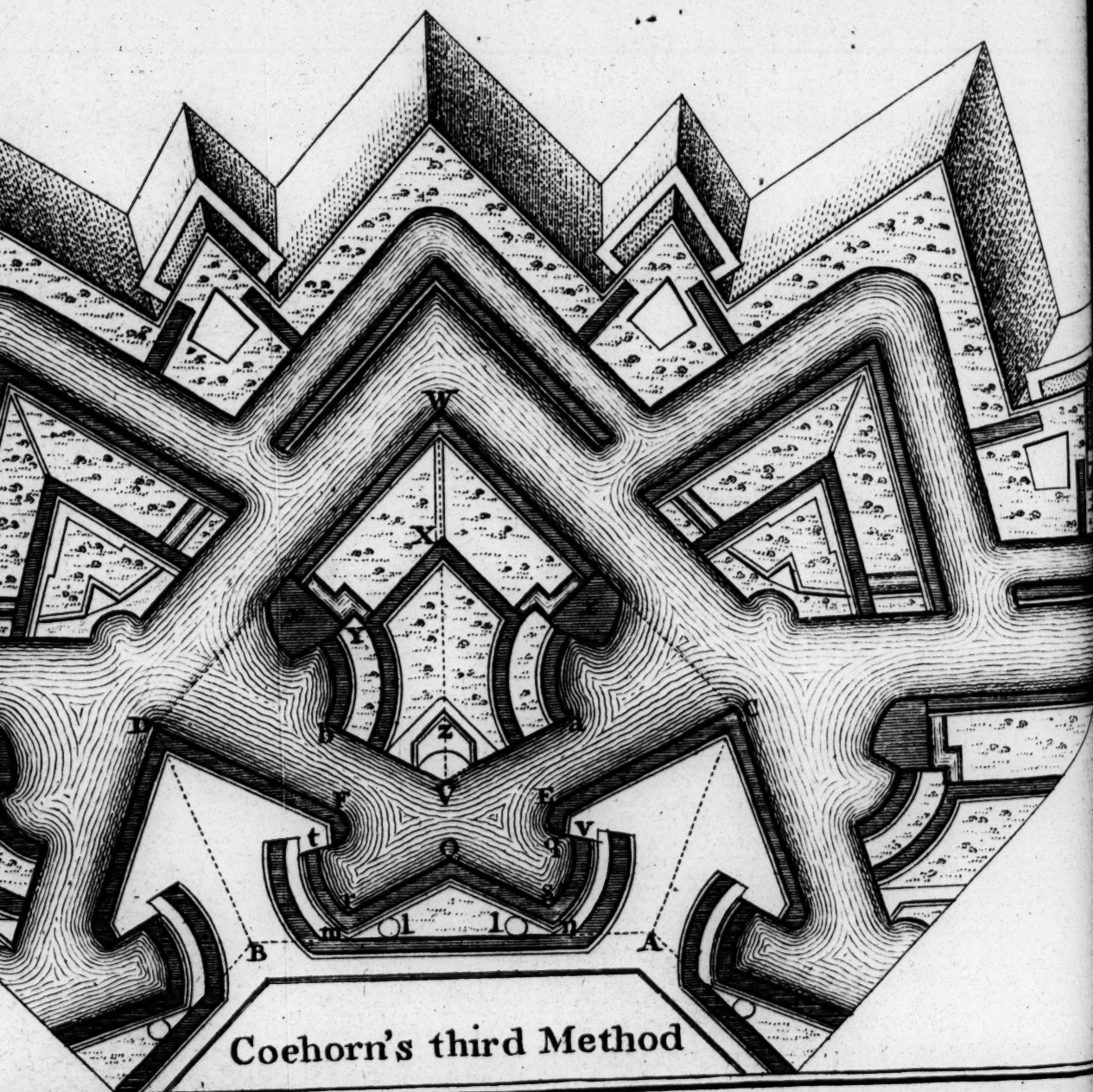
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Coehorn's third Method



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and the flanks are drawn parallel to their capitals.

The ditch before this work is 14 toises; as to the covert-way and glacis, they are the same as in the author's first method.

Construction of M. Coehorn's third method.

The author supposes an octagon, whose interior side AB is 110 toises; the semi-gorges An, Bm, 21; the capitals AC, BD of the bastions 64; and the saliant angles 85 degrees; the faces CE, DF of the bastions 54 toises; the parts Qs, Qr of the tenaille 32; the lower flanks, that is, those of the tenaille, are found by describing arcs through the points s, r, from the opposite saliant angles DC, on which are 20 toises set off as chords; and these chords serve to describe arcs of 60 degrees upon, for the required flanks.

From the extremities v, t, of these flanks, lines are drawn to the opposite angles D, C, and 6 toises set off from v to q; and upon qE the orillon is described as usual.

The higher flanks are described from the same centers, as the lower through the ex-
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tremities *n*, *m* of the curtain ; and their chord is 30 toises.

The wet ditch before the body of the place is 20 toises, and its counterscarp parallel to the faces of the bastions.

The capital *VW* of the detached bastion is 100 toises ; the faces are directed to the salient angles of the inner bastions ; the dry ditch behind the lower faces in the detached bastions is 20 toises ; and the higher faces are parallel to the lower, and 31 toises long : the towers *x*, and the ditch before them, are made in the same manner as in the first method. To find the flanks, make the semi-gorges *Va*, *Vb*, each 38 toises, and draw the chords of these flanks parallel to the capital *VW* ; and from the extremities of the higher faces draw also lines to the former, upon which the flanks are described as usual.

The counterscarp of the ditch before the redoubt *z*, is drawn from the extremities of the flanks parallel to the faces ; and at 6 toises from this, the faces of the redoubt are drawn ; 4 toises of which are cut off for the flanks.

The ditch before the detached bastion is 24 toises ; the ravelins, counterguards, covert-way,

way, and glacis, are the same here as in the first method.

There are little pits or points l, l, dug between the higher and lower curtains, to hold water, in order to prevent the passing from the tenailles to the flanks.

S E C T. III.

Containing the general Maxims of Fortification, applied in the Remarks on the preceding Authors, and others mentioned hereafter.

IN learning fortification, with an intention to make any progress in it, it is not sufficient to be capable of drawing lines, and to know the names of the different works; but it is necessary to be well acquainted with the principles or foundation on which the perfection and imperfection of a work depends; to be able to give reasons for what is done, and to be in a condition to judge upon good grounds, what is good and what is not so, in the various manners of fortifying, by all the different authors who have wrote on this subject.

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There are three considerations essentially required in a good and well-ordered fortification, without any of which it can never answer the ends proposed.

The first is, the EXPENCE necessary for the building of it: for should that be greater than the importance of the place requires, it is plain that such a place would be of no advantage.

The second is the NUMBER of troops, to guard and to defend it: for if a place should require so many, as that the expence, together with providing it with artillery, ammunition, and stores, be equal to, or exceed the revenue or advantage arising from such a place, it is manifest, that instead of being an advantage, it would be a disadvantage.

And the third is, the CAPACITY of the town with regard to the space taken up by the fortification: for if it should happen that the town could not contain a sufficient number of troops to defend it, besides the inhabitants, it is evident that it may be taken with less expence than another of fewer works, provided with the same number of troops; and therefore, such a fortification will not answer the ends proposed in fortifying it: St. Philip's Castle in *Minorca* is an instance of this

this fort; and such are M. *Coeborn's* systems, as we shall shew hereafter.

If the question was only to fortify a town strongly, without any other considerations, one might make outworks upon outworks without end; but if it is considered, that a whole state might be exhausted in the building of one single fortification, and which would require a whole army to defend it, it will easily appear, that the strength and bigness of a fortified place ought absolutely to depend on the importance it will prove to a nation.

Besides the general considerations, there are several particular ones; which are necessary in the well-ordering all the different parts, so as to make the best defence that can be for a place of that expence.

1. There ought to be no part, but what can be seen or defended by some other; which in the phrase of fortification is, all parts should flank each other reciprocally; for flanking or defending is the same thing.

For if there is any part that is not seen or defended, the enemy might approach that way under cover, and make themselves masters of it, without much trouble or loss.

2. The defence of every part should be always within the reach of musket-shot, so as to be defended both by great and small fire arms; for if it be only defended by cannon, the enemy may dismount them by the superiority of theirs, and then the defence would be destroyed at once; whereas, if a work is likewise defended by small arms, then, if the one is destroyed, the other will still subsist.

3. All the defences should be as nearly direct as possible; for it has been found by experience, that the soldiers will fire directly before them, without troubling themselves whether they do execution or not; there are other advantages in a direct defence, as we shall prove in the following propositions.

4. A fortification should be equally strong on all sides, otherwise the enemy may attack it in the weakest part, whereby its strength would become useless.

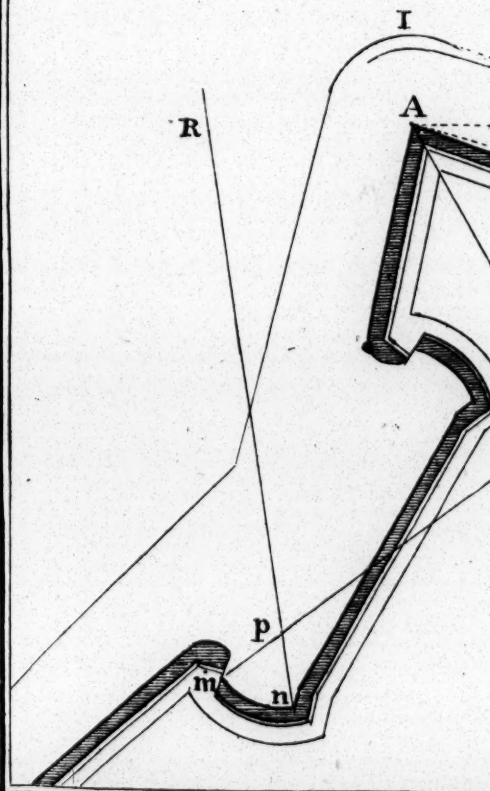
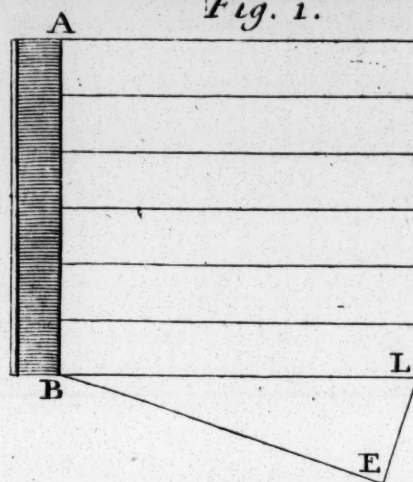
In a regular fortification, where all sides are equally fortified, it cannot happen otherwise than to be every where equally strong: but it is not so in the irregular, which requires great skill and knowledge to make a place so; and no author, that I know, has shewn how, and in what manner, we are to judge of the strength

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Fig. 1.

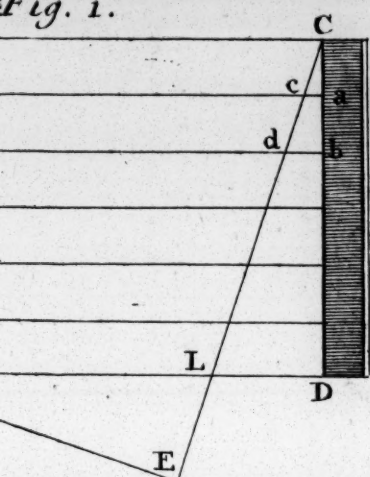


Plate XV.

Fig. 2.

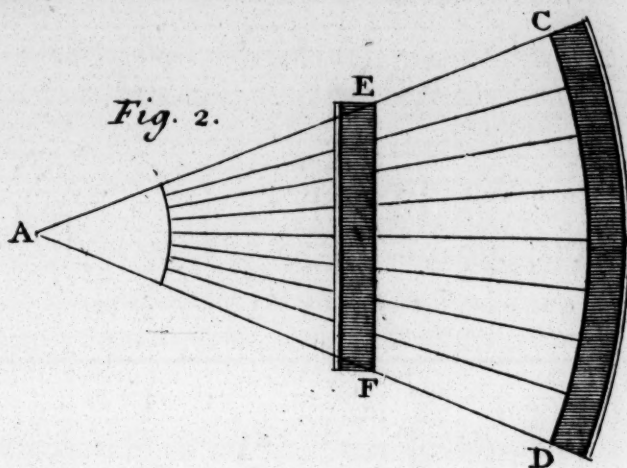
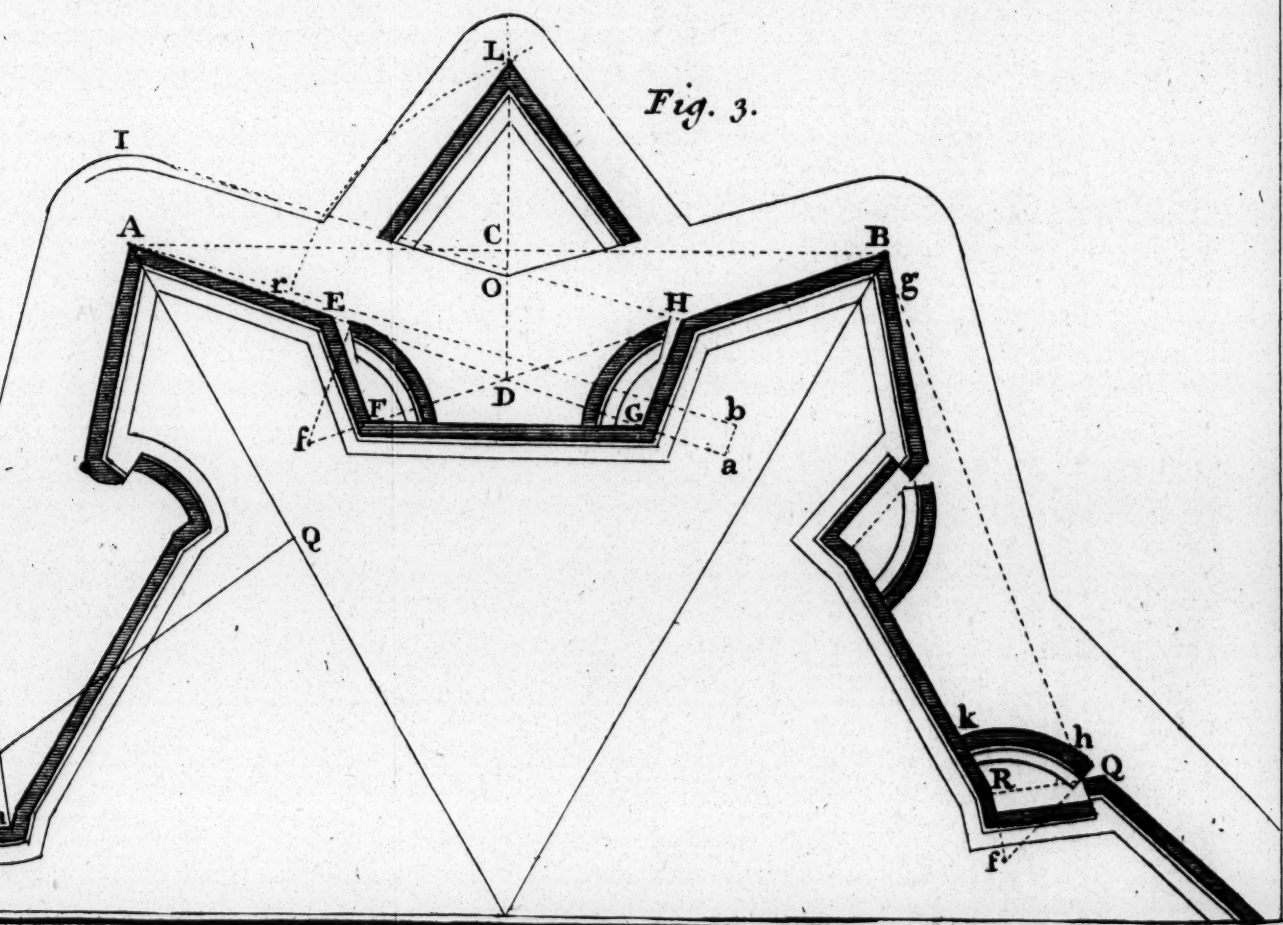
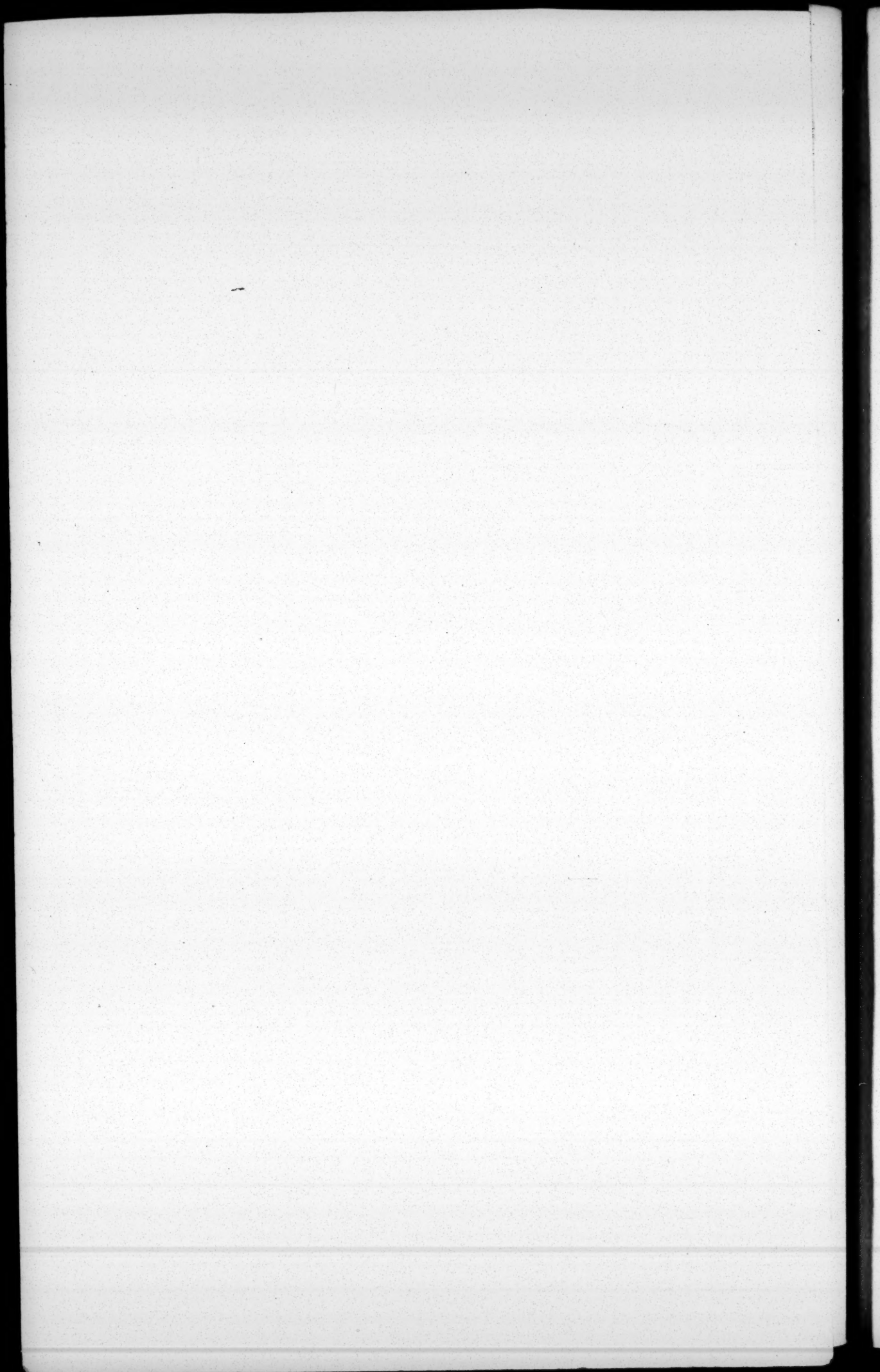


Fig. 3.





strength of the several parts in such a fortification, although they all agree to the importance of that maxim.

There are commonly several other maxims given by authors, which, in my opinion, ought rather to be proved, than only asserted.

PROPOSITION I.

Of two batteries which have equal fronts, that whose fire is direct is the most advantageous.

For let AB be an object to be fired at, Pl. XV. from the battery CD equal in front; then I say, that this battery CD, which is directly opposite to AB, is more advantageous than any oblique one, as CL, whatsoever.

For if CD be divided into any number of equal parts, such as ca, ab, &c. and from these points perpendiculars are drawn to CL, intersecting CL, in c, d, &c. then, if each of these parts of CD is the space necessary for one gun, or for one man; it is evident, that each of the corresponding parts Cc, cd, of CL, will likewise be necessary for one gun, or for one man: from whence it results, that there can be no more guns or men placed on the

THE ELEMENTS

oblique battery CL, so as to fire at the object AB, than on the direct one CD.

Now because the oblique battery CL is longer, and therefore of more expence than the direct one CD; and as the troops placed on the battery CL, fire with more uncertainty, especially when they are in a hurry, and in danger, than if they were placed behind CD, where they only fire directly forward; it evidently follows, that the direct battery CD is more advantageous than any oblique one whatsoever.

N. B. As the parapets are 3 toises, or 18 feet thick, it is not only uncertain, that the soldiers in a hurry fire at an object obliquely situated, but likewise very difficult and troublesome; so that besides the advantage of a direct defence, mentioned in the last proposition, this one is as much essential as any.

PROPOSITION II.

If the object AB be a counter-battery, the direct battery CD is still preferable to any oblique one CL whatsoever.

Let BE be perpendicular to CL produced; then the force, whereby a cannon-shot
from

from the battery AB would strike the battery CD, is to the force it would strike the oblique battery CL, as BL to BE; or because of the similar triangles BLE, CLD, as CL to CD; that is, reciprocally as the lengths of the batteries.

But the resistances of the batteries are reciprocally as the forces whereby they are struck, and therefore directly as the lengths or expences.

But the resistances of these batteries are only at the beginning, as the expences; for as soon as the least breach is made in the wall, they nearly equal: besides, if the guns of the battery AB fire directly, as they easily may, except the battery CL is very oblique, the resistances will be equal from the beginning; and as the guns are as easily dismounted on the oblique battery CL, as on the direct one CD, it evidently follows, that the direct battery CD is more advantageous than the oblique one CL.

COROLLARY.

From whence it follows, 1^o. that if the fire from the battery CD is to be directed towards a point A, the battery CD ought to be

Fig. 2.

be an arc of a circle, described from that point A, as center.

2°. And if the fire from the battery CD is to be directed to a line EF, of a greater or lesser extent than the battery, it ought again to be an arc of a circle, such that the radii CA, DA, drawn from its extremities, shall pass through the extremities E, F of the object, and make equal angles therewith.

PROBLEM.

To determine the several parts of a front of a fortification,

Fig. 3.

I. It is evident, that every part of the front AEF GHB, disposed in the manner described before, is seen and defended by some other part, as well as the ditch before it: for the flank HG, defends the ditch from the perpendicular CD to the face EA produced, as well as that face itself; the flank EF and half the curtain, and the flank EF defends the other half of the ditch from CD to the face HB produced, that face the flank HG and half the curtain; and consequently no part of this front can be approached, without being seen and defended by some other part.

II.

II. The next thing to be considered, is the length of the lines of defence AG, FB, which some will have to be within musket-shot, and others longer; the first say, that the principal strength of a fortification consists in the use of small arms, because the guns fire but slowly, are soon dismounted, and require much time to be remounted; whereas the fire from small arms is very brisk, and when one man is killed, another takes his place immediately; this is answered, that cannon does greater execution, and requires much trouble to make an epaulement to resist their force, whereas a moderate epaulement is a sufficient cover against small arms: besides, when the lines of defence are of a sufficient length, the several parts of the fortification become spacious and more convenient for placing both more guns and men in them; it also obliges the enemy to extend their trenches much farther, than if these lines were shorter.

But it is evident that, although the lines of defence are within musket-shot, there may be placed both so many men and cannon as are necessary to defend the works; and the works are likewise spacious enough for all other purposes.

From

From whence it is concluded, that the length of the lines of defence should not exceed the reach of musket-shot, which is commonly observed now-a-days; except when the front lies near a great river, and can hardly be attacked on that side, there they are often made longer.

It has been found by experience that a common musket-shot will hardly kill a man at a greater distance than 160 fathoms English measure; and therefore the lines of defence ought not to exceed that length when the front can be approached.

III. The length of the faces AE, BH should be such, that the flanks are of a sufficient length, and the gorges of the bastions not too narrow: they are never made less than 50 toises, nor greater than 70, in a fortification whose exterior side is 180 toises or upwards.

But as to the length of the perpendicular CD, it is no ways determined; for some engineers make it twice as long as others: they seem indeed to differ from one another, merely out of contradiction; since none of them, that I know of, has given any reasons for this practice; although it be plain, that the longer this perpendicular is, the greater
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the flanks will be, therefore the defence so much the greater likewise.

But then the expences increase also in proportion, and consequently the length of the perpendicular should be determined according to the expence which a state will be at, and according to the importance of the place.

IV. The position of the flanks is no more certain than the rest, since almost all engineers differ from one another in that respect: although it is evident that there must be a certain and determinate position better than any other.

For if their use be considered, the position will easily be known, as they are to defend the ditch before them: and it is a received maxim in fortification, that the direct defence is the best; and we have proved in the two foregoing propositions, that it has several advantages above an oblique: one it follows from the corollary after these propositions, that the flanks should be an arc of a circle described from the point of intersection, of the line of defence and opposite counterscarp produced, as center: or, because this arc differs but little from its chord, a right line which makes equal angles with the
7 line

line of defence, and the counterscarp produced.

Having thus determined the several parts of a front, we shall proceed in our examination of the several parts of the two foregoing authors fortifications.

Remarks on M. VAUBAN's first method.

This method is very simple, easily constructed, takes up but little ground, since the inward space left for buildings is to the space taken up by the fortification, comprehending ravelins and covert-way, as 970 to 1622 nearly; that is, the fortification takes up about one and a half more ground than the buildings: it is free from all surprizes, by its stone revetements, requires not many men to defend it, by the contiguity of its works, and is of very good defence, especially when some outworks are added; such as counter-guards before the bastions, lunettes, or tenail-lons, to cover and defend the ravelins.

But it must be confessed that his flanks are too small, since the enemy can always erect counter-batteries superior to them, as M. Coe-born observes (pag. 11. English edit.); but with

with regard to the battery, which he pretends to place in the ravelin, it is only a conceit, to impose upon the incautious reader ; since the fire from the whole curtain can always destroy that battery, as being much superior to it, and which cannot be silenced till the ravelin is taken and a battery erected in it.

The position of his flanks come pretty near to the true one, since the difference between the angles made by the flank, and the lines of defence, and counterscarp produced, is but about 2 degrees, which is inconsiderable in practice.

The manner of making retired flanks covered with orillons, is very good ; because the flanks cannot be discovered by any oblique batteries, and there may be a gun placed behind the orillon, which can be seen from no where else than from the breach in the opposite face of the bastion.

But for what reason he makes his retired flanks to be a circular arc of 60 degrees, is inconceivable to me ; since flanks are made for no other purposes, that I can find, than to defend the opposite ditch ; they ought evidently to be such arcs as we have demonstrated in the preceding problem, or right lines, which make equal angles with the
line

line of defence and counterscarp produced. But instead of defending the ditch directly, they defend all the part of the fortification contained within the angle QpR , made by the radii np , mp produced; so that it seems as if these flanks were made quite for other purposes than to defend the ditch; and what is more surprising still, all modern engineers follow him, as if it were the best defence that could have been invented; which plainly shews, when men go upon uncertain principles, how easily they are led into error. It is true, they imagine to get more room by making this sort of flanks, and that they resist better the fire of the enemy.

But these pretended advantages are founded upon as erroneous principles as the rest; for we have proved, that the flank made upon its chord will contain as many guns as that made on the arc itself, and resists better than the curved flank; as is easily demonstrated by mechanics.

His capital ditch is too wide; for if it were but about 16 toises at the salient angles of the bastions, and from thence drawn to the inner angles of the parapets at the shoulders, the flanks would then not be so much exposed as they are now, and there would
be

be less room on the glacis to erect counter-batteries.

We have shewn the general usefulness of tenailles, after their construction ; as likewise their perfections and imperfections.

As the ravelins are chiefly made to cover the flanks and curtain, M. *Vauban* ought not to terminate their faces on the shoulders of the bastions, but rather 3 or 4 toises beyond them : those of the second sort are still worse, because their flanks lay the flanks of the bastions still more open than the first : the third sort, which have redoubts within them are the best ; for they secure a retreat to the troops in the ravelin, and the enemy is obliged to raise a battery in the ravelin to destroy the redoubt ; it takes likewise a good deal of ground from the besiegers, who cannot therefore erect such large batteries in them, against the curtain or flanks.

The lunettes are of a very good defence, especially when there is a bonnet to cover the salient angle of the ravelin, as we have mentioned in their construction : the same thing may be said in regard to the tenaillons.

Instead of making the semi-gorges of the bonnet 15 toises, I would make them but 8 or 10 at most, whereby the defence of

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its ditch and covert-way would be greater, and the besiegers would find less room in them for batteries.

The faces of the lunettes should be one perpendicular to the face of the ravelin, and the other to that of the bastion, in order to be defended in a direct manner, which ought to be observed in all works, if possible.

Some authors object against the lunettes, on account that the ditch, which is defended by the ravelin, has no defence left as soon the ravelin is taken; but as it is hardly possible to take the ravelin without being first master of the lunettes, their objection is of no consequence; and should the besiegers be imprudent enough to pass by the lunettes without taking them, they must certainly suffer much more than if they had.

The countersguards before the ravelins are but seldom made; for a redoubt within the ravelin answers the same purpose, and is less expensive: but as to those before the bastions, they are some of the best of all outworks, when they are well constructed; since the enemy cannot pretend to make a breach in the bastion, nor destroy the flanks before they are masters of the countersguard; and then they have not sufficient ground to
make

make batteries in them, to destroy the flanks and make a breach.

All tenaillons and counterguards should have retrenchments, such as that marked by the letter K, fig. 6. in the second plate : for by this means their defence becomes much more considerable than without them. This the *French* have done in their counterguards lately constructed before the bastions at *Lille*, and in the tenaillons at the front which was attacked by Prince *Eugene* and the Duke of *Marlborough* in Queen *Anne's* war ; when these tenaillons made one of the best defences that ever was known.

M. *Blondel*, and after him M. *Coehorn*, make their ramparts so narrow, as to leave no room to place guns upon them ; and this is to prevent the besiegers from erecting batteries there, whereby they will be obliged to bring earth from the covert-way, in order to destroy the flanks. But as these counterguards are only defended in the front by small arms, they can make no great resistance ; besides, the besiegers may make a few mines under them, and so blow up as much as will discover the faces and flanks from the covert-way ; whereas, if their ramparts are 7 or 8 toises broad, they cannot be destroyed

by mines ; and there will nevertheless not be sufficient room to erect batteries in them to destroy the flanks.

I would chuse to make these countersguards as high as the bastions themselves, in order that the enemy might not discover the bastions but from within the countersguards ; by which means the fire of the whole bastion would defend the countersguards in such a manner, as to make it almost impossible to make any lodgment there.

The horn and crown works are chiefly made, to take away a spot of ground which might be advantageous to the enemy ; to cover the gates of the town, or to build store-houses and hospitals in them.

The flanks are too small, as well as the fronts themselves, and the ditches before the branches are too obliquely defended : the retrenchments made in them are very good, to retire behind when the work is taken, and to disturb the lodgments made there.

These kind of works ought never to be made, but upon the above-mentioned occasions ; for their building is very expensive, and cheaper works would be of a much better defence ; notwithstanding M. *Vauban* has too profusely made them, in the fortifica-

tions of *Tournay*, *Ipres*, and in several other places ; and placed them often so near each other, as would incline one to believe, that he rather intended more to terrify an enemy by their number, than to strengthen the place.

The covert-way seems to be of a sufficient breadth to contain the necessary troops to defend them, and the traverses are absolutely necessary for their defence ; contrary to the opinions of M. *Coeborn* and others ; for without them the covert-way may be enfiladed by the ricochet batteries, from one end to the other : besides, when the salient angle is attacked, the besieged have a secure retreat behind them ; and so may be defended to the last extremity ; experience has sufficiently proved their usefulness, for at *Lisle* a traverse was three times taken and retaken.

M. *Vauban* invented three different manners of covering the passages round the traverses at the salient angles ; the one by cutting the passes out of the glacis, as in plates VIII and IX, the other by making a kind of shoulder before them, and the third in the form of the teeth of a saw, which he calls *en Cremaille*, so as the passage may be seen

and defended from behind the traverse which forms the place of arms at the re-entering angle ; which is undoubtedly preferable to the other two, and has been practised in all the fortifications built in latter times.

I am not ignorant that the whole front of the covert-way is sometimes attacked at once ; in such a case, the traverses seem to be useless ; but as this only happens when the garrison is very weak, or the enemy presumptuous and unskilful, they generally pay dear for their rashness, and seldom can maintain their ground. Besides, the besiegers may drive the troops out of the covert-way with their ricochet batteries, when they are as yet far off, so that it is of no manner of use after the second or third day of the attack ; but to prevent the traverses being useful to the besiegers in covering them, I would chuse to make a small mine under them, and when they can no longer be defended, to blow them up.

The arrows and detached redoubts are of no great expence ; and nevertheless are very good in hindering the enemy from beginning their trenches too near, and to disturb them in their approaches ; but the redoubts are liable to be surrounded by the trenches and
taken

taken by the gorge, if they are not well protected from the covert-way or some other outwork; for which reason they should never be farther from the covert-way than about 50 toises; and if they were mined so as to be blown up when they can be no longer defended, they would afford no shelter to the enemy when they are taken.

As to the second ditch and covert-way, they being works only made of earth, are of no great expence, and yet may make a very good defence, especially when the slope of the first glacis goes as low as the surface of the water; or when the water can be raised in time of a siege, so as to overflow the best part of the first glacis; it would oblige the enemies to bring earth from the second glacis to retrench themselves upon the first, which would cost them a good deal of time and trouble; and as this must be done under the grazing fire of the covert-way, it could not be done without much cost and danger: the second covert-way should be not above a foot above the surface of the water in the ditch, to oblige the enemy to bring earth for making their trenches in it.

M. *Vauban* was so sensible of the goodness of these works, that he never failed to make

them where-ever he found the ground convenient for it; as may be seen at *Sarre Louis*, at the city of *Lisle*, and in other places.

Remarks on M. VAUBAN's second and third methods.

The design of the second method is to fortify an old town already inclosed by a rampart; and it is for that reason that he begins within and fortifies outwards, contrary to his other methods, as being more convenient in this case: the tower-bastions are joined to the old wall, and have underneath a magazine in the form of a cross; all round this magazine are casemats, or cellars, to hold both men and guns; those in the flanks have each an embrasure which opens into the ditch, and those in the faces have embrasures so as to fire out of one into the other when taken by the enemy; and above is a parapet of 12 feet thick with embrasures, as may be seen in plate XI, where a plan and section of a tower-bastion is represented.

As these towers are almost a solid bulk of masonry, they must be of great expence, though their resistance can be but little; for it has been found by experience, that the casemats

mats are but of little use, because, as soon as they have fired once or twice, the smoak will oblige the defenders to leave them, notwithstanding their smoak-holes.

In my opinion, instead of attacking the towers themselves, the ramparts near the flanks of the countersguards may be attacked; and then the flanks of the towers may be destroyed by the guns placed on the flanks opposite to them, which are already made for that purpose, and want nothing else but embrasures.

It may be concluded, that the strength of these towers does by no means answer their expences; and that if small bastions were made instead of them, without casemats, they would be much better, and of less expence.

As to the countersguards, they are very good, and may be defended to the utmost extremity, without exposing the town to be taken by storm; but their flanks are too small, and are easily destroyed from the opposite covert-way; there should either be two, or if but one, it should be pretty large.

M. *Vauban* considering, that as soon as a breach was made in the faces of the bastions, and the passage over the ditch finished, the
garrison

garrison is always obliged to capitulate, whereby the little defence they make by no means answers the great expence in constructing them, rightly judged, that if they were detached, it would be much better; for by this means they may be defended inch by inch to the very last, without exposing the town.

For these reasons M. *Vauban* invented his third method; but as it differs only from the former in having two small flanks in each curtain of about 4 toises, which can hardly hold two guns each, and therefore add no great strength, the same exception which we made against the second method, may be made likewise against this.

M. *Vauban* has been censured for making flanks to his ravelins in these two last methods; because the flanks of the counter-guards are said to be obliquely seen thereby, from the covert-way before the ravelin. But as they can be seen only under a very small angle, they cannot receive any damage from thence; and these flanks defend the salient angle of the counterscudards extremely well; this objection has not the least foundation. I may venture to say that all the works of the second and third method are as properly made
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and may make as good a defence as could be wished ; the tower-bastions and the small flanks in the third excepted.

Remarks on M. COEBORN'S first method.

Before we enter into any particulars of this method, it is necessary the reader should know, that M. *Coeborn* wrote his book before he had acquired that great experience, for which he has been so justly esteemed one of the greatest engineers that ever was, in order that they may not be misled by the excessive praises bestowed by some authors, on account of his works which are published, although impracticable in themselves, and undoubtedly thought so by M. *Coeborn* himself, after he was a better judge of fortification, as evidently appears by the towns he fortified afterwards ; for if he had thought that his works could really make that prodigious defence, which he pretends in his writings, it would be very strange, that he should not have made use of them, when he had an opportunity to do it.

Having thus shewn in general, that the author himself disapproved his works ; we

shall now proceed to shew the advantages and disadvantages of the particular parts.

We shall begin with shewing that the expence which he pretends to be much less in the building of this fortification, than that of the *French* method, is not so inconsiderable as he saith would persuade the world: first the room within for buildings, is to that taken up by the fortification, as one to three nearly, rather more than less; and as he makes his inward polygon equal to that of M. *Vauban's* exagon; and we have found, that the inward polygon is to the space taken up by the fortification, as unity to $1\frac{1}{2}$; the fortification of M. *Coeborn's* method takes up just as much ground again as that of M. *Vauban*, and therefore double the expence for removing the earth; but then he says, that much less masonry is required here than there, and it is upon this he grounds his frugality; but it has been found by experience, that works of earth cost as much in time, as those made of stone, on account of their continual repairing; so that in the whole it appears, that M. *Coeborn's* exagon costs more, or at least as much as M. *Vauban's* exagon; then if we consider the lowness of these works, and how easily they may be surpris'd, they will

will require at least three times the number of troops and ammunition to defend them, as the *French* one.

For when a place is out of danger from being surpris'd, there requires but a few troops to guard the works which are not attacked ; whereas, on the contrary, the others must be every where equally guarded ; otherwise the besiegers may make a sham attack on one side to draw the besieged that way, and surprise some of the works on some other side.

The next thing is to examine whether the different works are constructed in the best manner : first, as to the upper and mean flanks, they seem to be the only thing the author borrowed from the *French*, and is just the worst of all M. *Vauban's* works, as we have shewn heretofore : the curtain of the tenaille would have been better straight than crooked ; the towers being but small, and a parapet quite round them, are very dangerous, and a fair mark for throwing shells, by which there is no security for those within : the dry ditches and lower faces of the bastions and ravelin are easily enfiladed by the ricochet batteries ; and the palisades placed in them, to secure a safe retreat, are very dangerous ; because if a shot hits them, the splinters will do more
mis-

mischief than the shot itself, as to the casemats in the towers, they are very bad, as we have shewn before, speaking of the tower-bastions; the stone galleries made under the ramparts of the lower faces of the bastions and ravelins, seem to be useless, on account of the smoak, for the same reason as all casemats are; and if some grenadiers go between the loop-holes and fling a few grenades into them, they must infallibly destroy those within.

The redoubt in the gorge of the ravelin is of excellent use to secure a safe retreat to the besieged, which is in my opinion of the greatest consequence; for if the troops have no retreat, they can never defend a work so well as they might do otherwise.

The wet ditch before the lodgment and the dry ditch of the ravelin, are in a wrong place, since they are directly opposite to the ditch before the counterscarps; and these lodgments themselves being only a stone wall, are easily destroyed by the ricochet batteries.

The rampart of the counterscarps being only 28 feet broad, including the parapet, they are easily destroyed by mines, as we have mentioned before, speaking of counterscarps; no cannon can be placed in them: neither are their ditches defended by cannon, except

except from the higher faces of the ravelin ; and as to the covert-way, it is by much too spacious, and liable to be enfiladed from the beginning of the siege, by the ricochet batteries placed before the first parallel ; so that of this spacious work, there are only the places of arms which can make a defence ; the redoubts in the places of arms being inclosed quite round, are dangerous to defend, for a few shells thrown into them must inevitably destroy those within, or oblige them to quit the work ; and they are contrary to the general maxim of fortification, that no part whatsoever should be so as not to be seen or flanked by some other ; but here, if the enemy gets once possession of these redoubts, the walls near the counterscarp will cover them in such a manner, as not to be seen from any part of the fortification.

As to the coffers made in the glacis, they cannot much retard the approaches of the enemy, being only defended by small arms ; so that a few gabions filled with earth will easily cover the besiegers against the fire of these works.

It is most certain, that when *M. Coeborn* published his book, he knew nothing of the ricochet firing, the invention of which being
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of later date ; and therefore was not aware of the inconveniencies which attend now-a-days these low works ; otherwise he would never have made use of them ; and it is undoubtedly for this reason, that he never put them in practice afterwards, when he was acquainted with this manner of firing ; the manner of fortifying *Bergen-op-zoom* differs so little from *M. Vauban's* first method with orillons, that I took it for the very same till I was better informed ; and this place is undoubtedly a master-piece of art.

The comparing of this method with the *French* exagon, fortified with ravelin and covert-way only, is not just ; for the one takes up twice as much ground, and requires about three times more troops to defend it than the other, and therefore there ought to be no more comparison between them, than there is between a place of few works, and another of a great many ; but to make the comparison just, the author should have compared his exagon with a *French* one of an equal number of works.

M. Coeborn's second and third methods are absolutely impracticable ; for their fortification takes up five times as much ground as the town ; and therefore the town would hardly

hardly hold more people, than the number of troops required to defend the fortification, besides the store-houses for the prodigious number of artillery and stores.

As we have shewn the faults M. *Coehorn* has committed in his works, which he has published before he acquired that great knowledge for which he is so justly esteemed as one of the greatest engineers, justice requires that we should likewise mention his extraordinary skill shewn in fortifying *Bergen-op-zoom*; which is one of the best contrived fortifications in all Europe.

Having thus finished our examination of the methods of two most celebrated authors, we shall now proceed to shew in what manner the several parts of the body of the place are to be constructed, so as to be capable of the best defence, proportionably to the expence.

A new Construction.

Let AB be the exterior side of any length, Plate XV.
suppose 180 toises; make the perpendicular Fig. 3.
CD of any length, as the 6th, 5th, or 4th
part of the exterior side, according to the
expence or importance of the place: here

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it is the 6th part or 30 toises, set off 50 toises or more for the faces BH, AE, or rather $\frac{2}{7}$ of the exterior side; from the salient angle A describe an arc with the radius AI of 20 toises, that is, 2 or 3 toises more than the breadth of the ditch; draw from the opposite shoulder H a tangent HI to that arc, and from the angle A the indefinite line Ab parallel to that tangent; then if from the angle A, as center, an arc a b be described with any radius, the flank GH is drawn parallel to the chord a b: one of the flanks being thus found, the others will be found by taking the distance DG, between the perpendicular and the angle of the flank, and carrying it from the extremities of all the perpendiculars on the lines of defence, as from D to F; this being done, the counterscarp of the ditch is drawn parallel to the line HI or to Ab; and having the point or re-entring angle O, its distance from the extremity of the perpendicular, being carried all round, will give the re-entring angles before the other fronts.

The tenailles h k, which M. *Bellidor* has invented, and called them *Rams-horns*, are described, by setting off 3 toises from the shoulder Q of the bastion to the point h, and drawing

drawing $h f$ perpendicular to the line of defence ; then its intersection f , with the other line of defence produced, will be the center of the arc $h k$.

To construct the Ravelin.

Set off 12 or 15 toises from the shoulder E to the point r , in the face of the bastion, and from the angle G of the flank, as center, describe an arc through the point r , meeting the perpendicular CD produced at L ; from this point L draw the faces, so as when produced to fall on the faces of the bastions within 3 toises of the shoulders ; the ditch of the ravelin is 12 toises.

To construct Retired Flanks.

Find the flank QR as before, on which set off 5 or 6 toises for the shoulder or orillons ; and from a point g in the opposite face of the bastion at 5 toises from the salient angle B , draw the broken part of the flank ; then draw the retired flank parallel to the line QR , at 5 toises distant from it : the orillon may be made round in the manner of *M: Vauban's*, if it be thought proper.

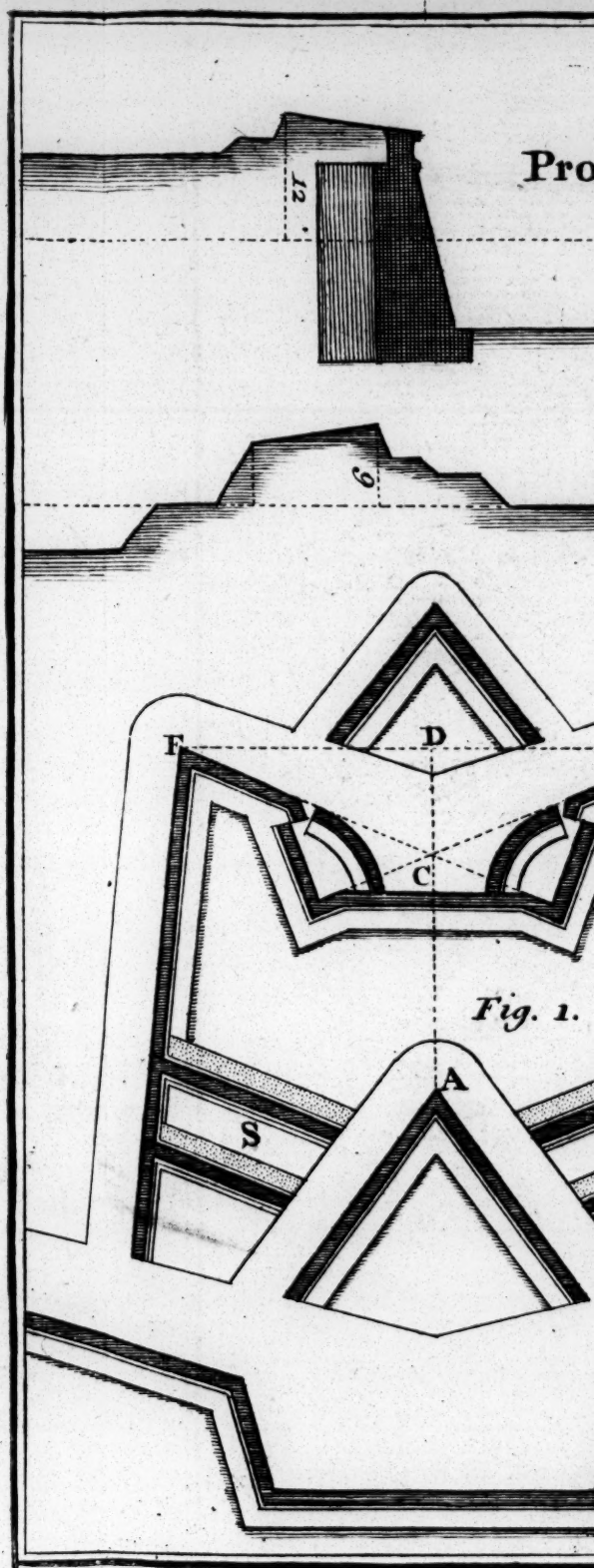
Remarks on this construction.

This construction is general, let the exterior side AB be what it will; the flanks make equal angles with the lines of defence and the counterscarp produced, and therefore defend the ditch in the most direct manner; the counterscarp terminates at the inner angle of the shoulder, so that the gun placed in that angle grazes all along the counterscarp: the ravelin is of a due proportion, its salient angle is neither too narrow nor too open, and its faces cover the flank of the bastions sufficiently from being seen obliquely.

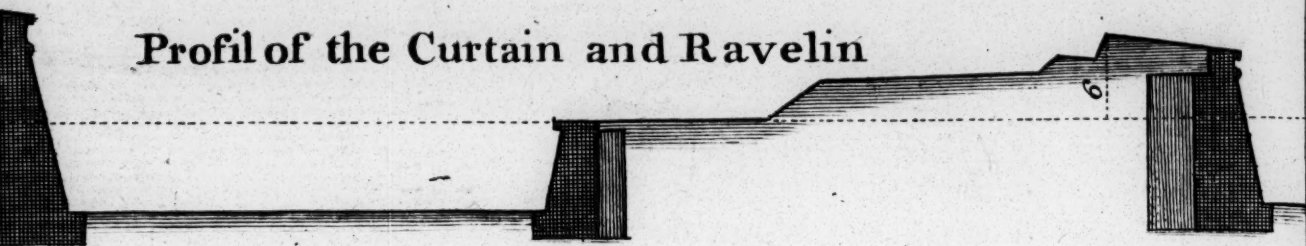
The orillons are made 5 toises long only, which appears to me sufficient for covering the retired flanks, and by making them so, the flanks are larger than if they were made 9 toises, as M. *Vauban's*: the rams-horns have several advantages over the common tenailles; they cannot be enfiladed, leave more room between them and the flanks, so that the rubbish from the flanks do not incommode the troops in the rams-horns; and being circular, they see not only the ditch directly, but likewise the level ground of the ravelins, and the opposite covert-way; they also resist the opposite batteries

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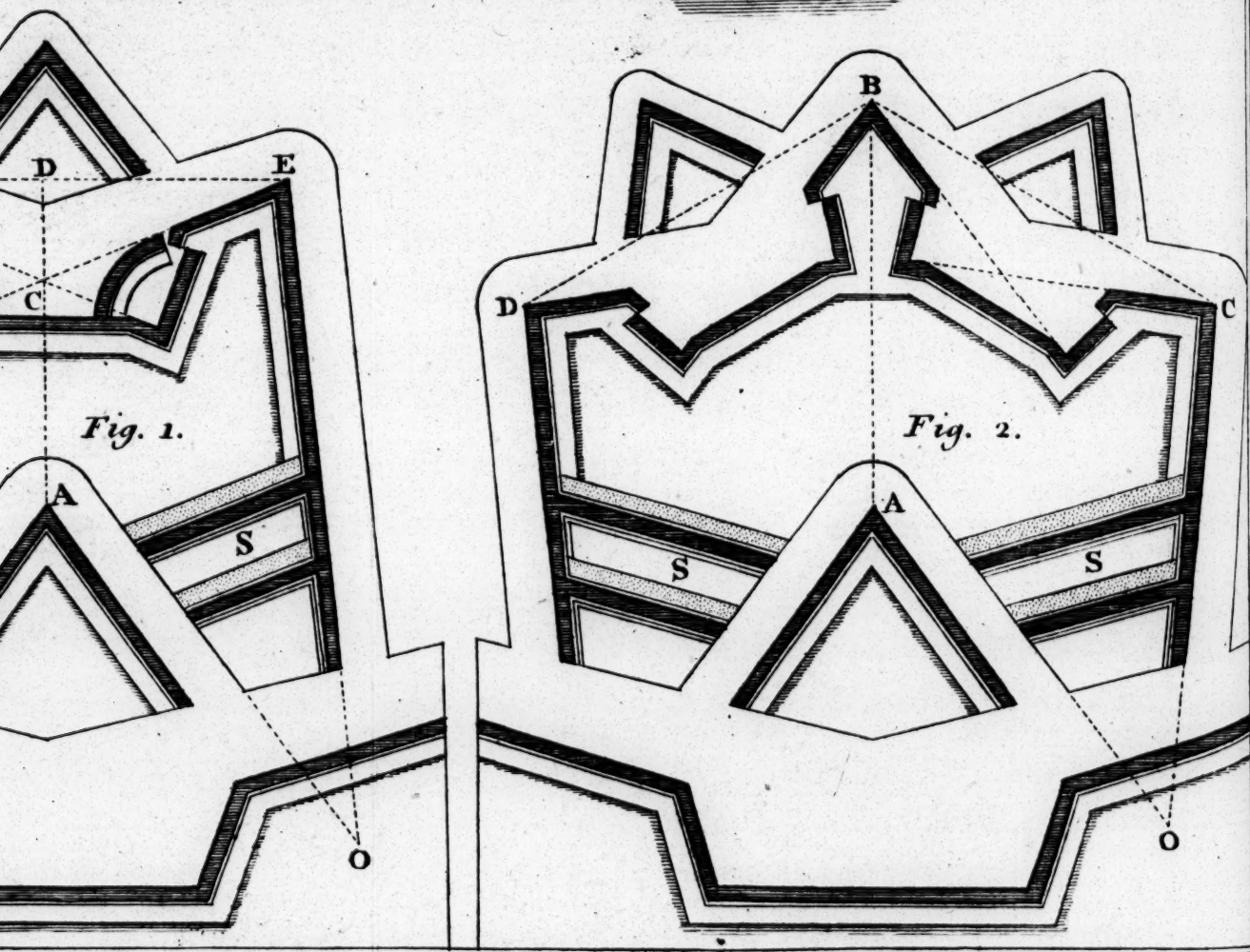
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Profil of the Curtain and Ravelin



Profil of the Retrenchments



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teries much better, and are of less expence in their construction, and therefore preferable in all respects to the common tenailles.

If these flanks are not thought sufficient, another might be made behind them, in any polygon above an exagon, without making the gorges of the bastions too narrow; there might even be made another in an exagon, provided the first be only 20 feet retired, and this would be sufficient to cover it.

By drawing the line which terminates the retired flank from a point g within five, or rather ten toises from the saliant angle B of the opposite bastion, a gun may be placed at the extremity of that flank, which sees into the breach made in the face AE, and which cannot be seen from any part of the opposite covert-way, and therefore cannot be dismounted but by mortars, which is not so easily done.

To construct Horn and Crown-works.

When there is a necessity to construct horn or crown-works, either to cover a gate, or to occupy a spot of ground which might be advantageous to the besiegers, and which can no other ways be taken into the fortification; then the distance AD from the front of

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Pl. XVI.
Fig. 1.

the horn-work to the salient angle A, of the ravelin or bastion, should not exceed 100 toises, otherwise the branches cannot be well defended by the opposite faces of the bastions or ravelins; they should only be about 80, as in this figure, if it may be done; the front EDF is 120 toises; the perpendicular DC one fifth part of the exterior side, that is, 24, and the faces 30; and so in proportion to the exterior side: the arc described for finding the position of the retired flanks, should have a radius of 15 toises, and the ditch 12; that the counterscarp of the ditch may terminate at the extremity of the orillon which is but 5 toises long, the flanks are as much retired, and made in the same manner as those in the body of the place: we have added rams-horns instead of tenailles, in order to get as much flank as could be.

The branches of the horn-work terminate on the faces of the bastions within 30 toises of the shoulders, the ditch is 12 toises, the parapet of the horn-work is 12 feet high, as well as that of the ravelin which is constructed in the manner described before; that is, by describing an arc from the angle of the flank through a point in the faces of the horn-work, 12 toises distant from the shoulder, whose

whose intersection with the perpendicular CD produced, will give the saliant angle of the ravelin; the faces terminate within 3 toises of the shoulder; the ditch of the ravelin is but 8 toises; the retrenchments S are constructed by producing the branches, and the counterscarp of the ditch before the ravelin, till they meet; and by setting off 25 toises on that counterscarp, for the first, and 20 more for the second; then if from the point O, as center, arcs are described through these points, which meeting the branches will give the other points through which the retrenchments pass; they are made of earth only, their parapets should be but 9 feet higher than the level ground, with a berm of 6 or 8 feet, and a dry ditch of 4 toises before them.

The distance AB or radius of the arc, Fig. 2. which passes through the points C, B, D of the crown-work, is 100 toises, and should not exceed 120 or 130 at most; the exterior sides BC, BD are 100 likewise; the perpendiculars 20, that is, one fifth of the exterior sides; the faces 26; the radius of the arc, which serves to determine the position of the flanks, is 15, and the ditch 12; the branches terminate on the faces of the bastions within

H 4

30 toises

30 toises of the shoulders, in the same manner of those of the horn-work ; the ravelins are constructed in like manner as in the horn-work ; as likewise the retrenchments S, except that the first is only 20 toises from the great ditch.

Remarks on this construction.

The branches of these works are more directly defended by the faces of the bastions, than those which are usually made ; the flanks much larger, and covered by the orillons, and the rams-horns added to the flanks, make together a larger battery than can be erected against them, which is a maxim in fortification, to be observed, if possible ; otherwise the flanks are soon destroyed, the faces become defenceless, and so the work may easily be taken.

It is to be observed, that there should be a row of palisades placed in the middle of the dry ditches before the retrenchments S, and the parapets of these retrenchments should be a row of palisades placed about 3 feet above the berm horizontally, or rather with the points a little downwards, that the grenades may roll off into the ditch.

For,

For, if this precaution is not taken, the enemy might pursue and follow the troops which defend these works, so as to enter with them into the retrenchments, and thereby get masters of them at the same time the horn-work is taken.

Because the retrenchments S making equal angles with the branches, and the counter-scarp of the ditch before the ravelin, they will defend the level ground before them in the most direct manner, as we have shewn in the construction of our flanks, and therefore is preferable to any other position that can be given to these retrenchments.

The reader will easily imagine, that there must be a barrier or gate in the ditch near the branches of the horn or crown-work; likewise a sally port under the parapets, for the troops to retire through, when the work is taken.

Construction of a place with detached Bastions.

As a garrison seldom or never suffers the enemy to make an assault on the bastions when they are joined to the place, for fear of being put to the sword, and the town sacked,

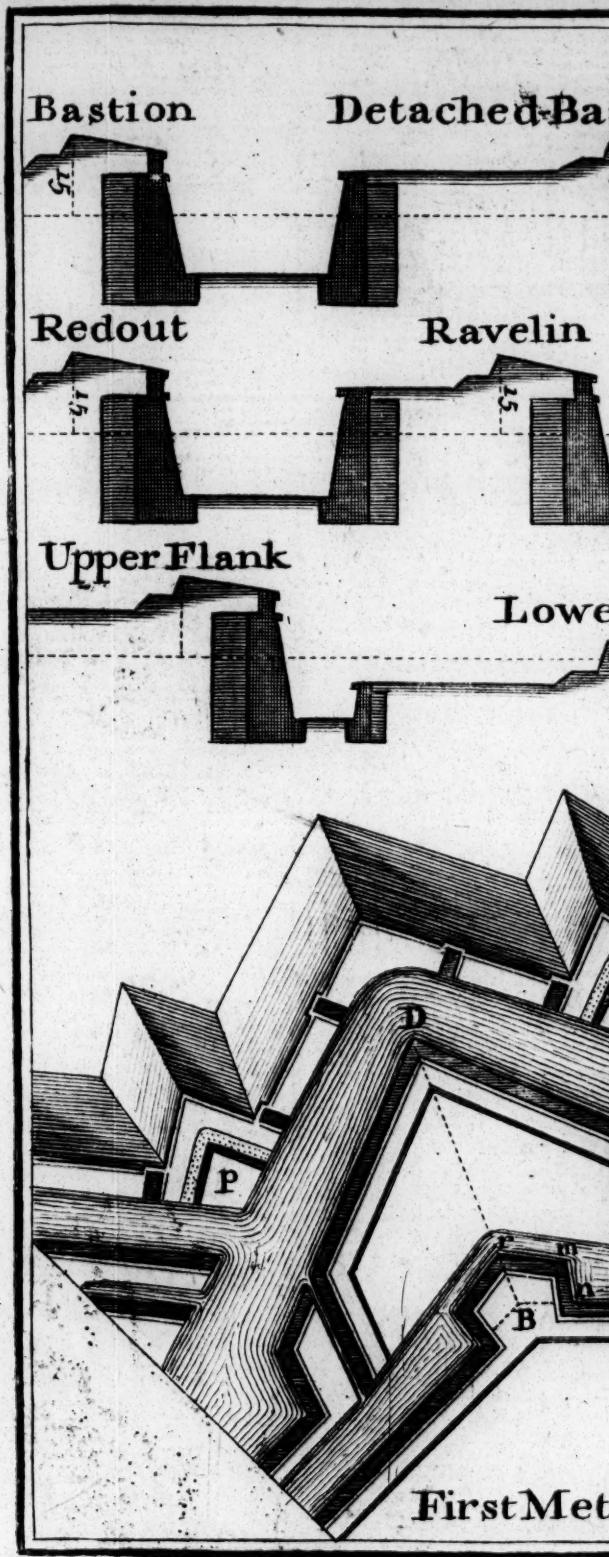
facked, the bastions are never capable of making a defence answerable to the expence of building them; it cannot therefore be said, that such a place answers the intent for which it was fortified.

It was for this reason, that M. *Vauban* invented his second and third methods, as we have already mentioned in their construction: but as his tower-bastions will hardly answer the great expence of their building, we thought it would not be improper to propose two methods, of the same nature, in which it has been endeavoured to make every part answerable to the expence of building them; as likewise to dispose them in such a manner, as to make the best defence that they will admit of.

PL. XVII. Let the interior side AB of an octagon be 130 toises; take Ab, Bn, equal to 12 toises, for the semi-gorges of the small bastions, and as much for their capitals Ac, Br, from the points c, r, draw the lines cn, rb to the extremity of the gorges, and make the flanks bd, nm perpendicular to the lines of defence; the ditch is 6 toises at the salient angles c, r, and its counterscarp drawn to the extremities of the flanks of the detached bastions.

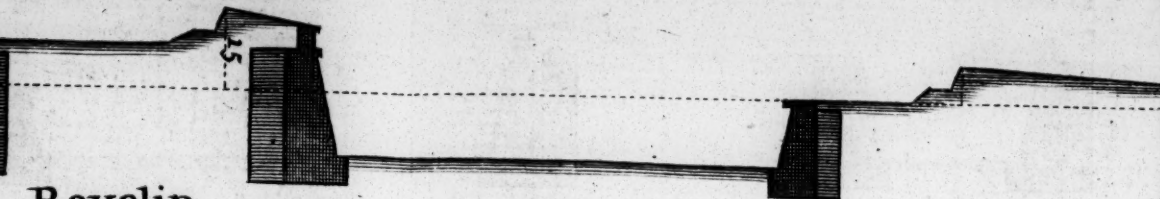
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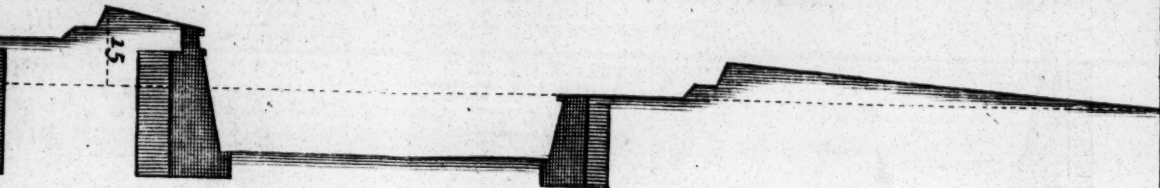


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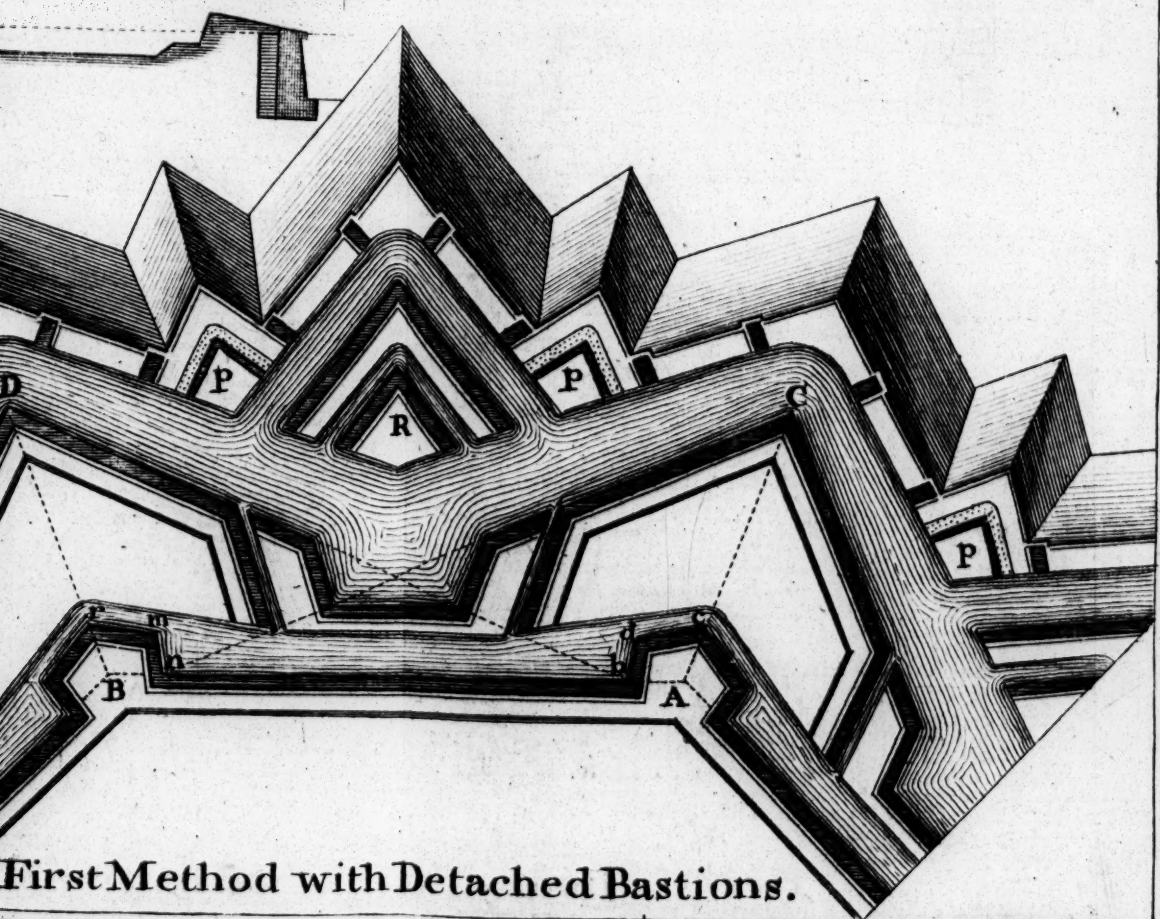
Detached Bastion



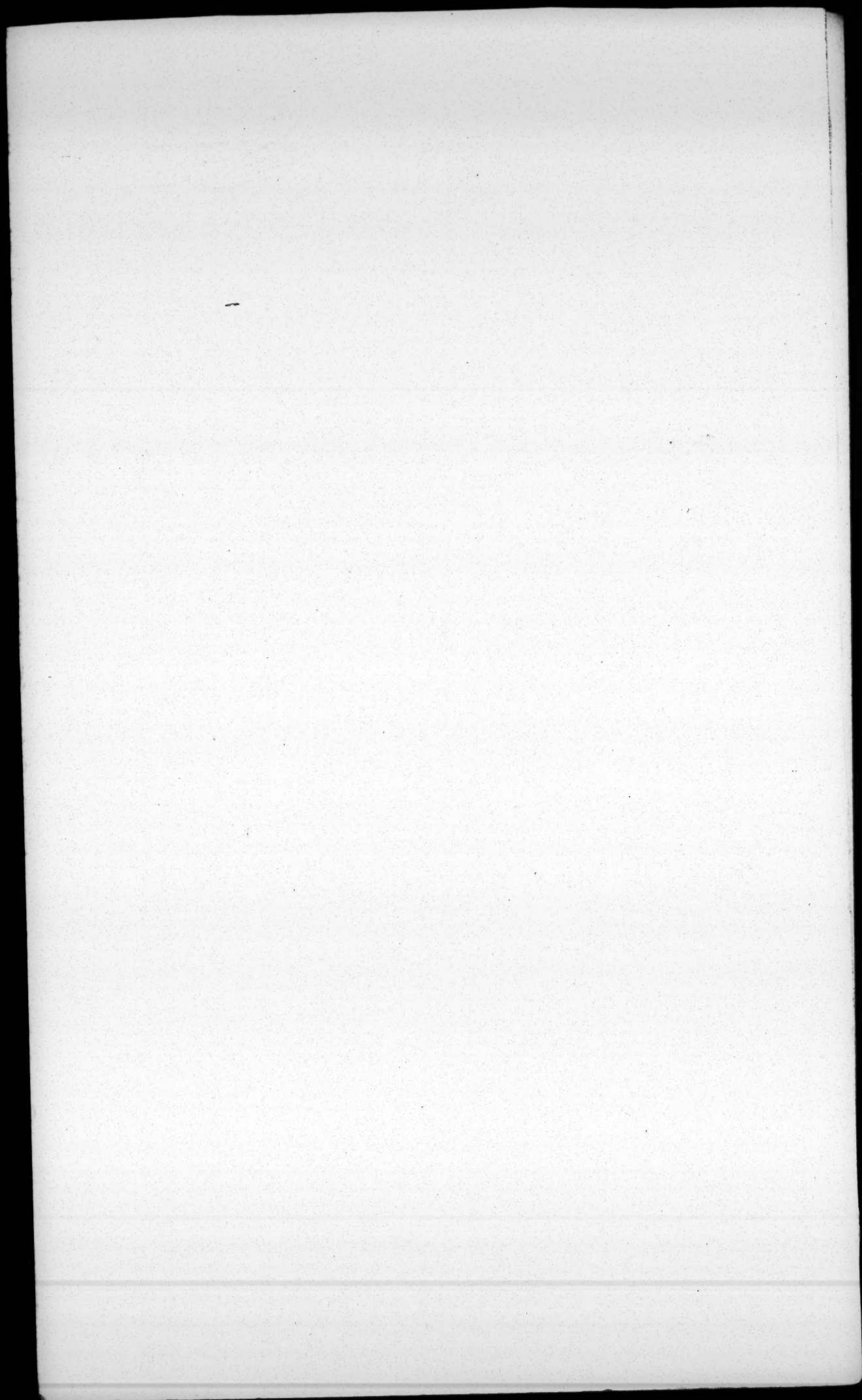
Ravelin



Lower Flank



First Method with Detached Bastions.



The capitals *c C*, *r D* of the detached bastions are 55 toises, and the lines of defence are drawn to the extremities *b* and *n* of the interior flanks; 18, faces are 60; the radius of the arc, which serves to determine the position of the flanks, 18, and the ditch 16 at the saliant angle.

The ravelin is constructed, by describing an arc from the extremity of the flank, as center, through a point in the opposite face of the bastion, within 20 toises of the shoulder, which arc intersects the capital of the ravelin at the saliant angle; the faces terminate within 5 toises of the shoulders, the semi-gorge of the redoubt *R* is 15, its faces parallel to those of the ravelin, and its parapet 2 toises; the ditch of the ravelin 12, and that of the redoubt 6.

The semi-gorges of the places of arms are 20 toises, those of the stone redoubts *p* within them 12; the faces of the places of arms are 25; and those of the redoubts, parallel to them, with a dry ditch of 3 toises before them; the covert way is 6, and the glacis 20.

The faces of the tenailles are 16 toises, the passage between them and the flanks of the bastions 3; their flanks are parallel to
the

the others, the curtain is drawn through the points where they meet the lines of defence, and the inside of the tenailles is terminated by lines drawn through the extremities of the flanks of the detached bastions.

Remarks on this construction.

This method answers perfectly the intent for which M. *Vauban* has invented his second and third methods; for the small bastions are more extensive than the tower bastions, and yet cost much less in their construction; and tenailles adding a lower flank to that of the detached bastions, renders there fire superior to that of the besiegers; and to secure the lower flanks from the enfilades, a part of the faces, next to the shoulders, should be raised about 3 feet higher than the rest, for the space of 4 or 5 toises.

The town wall should be of the same height, and no more than the detached bastions and ravelin; for which reason we made them all 15 feet high, the tenailles 3, and the ditches 12 feet deep; and if the works were only 12 feet high, it would be sufficient.

It

It is the opinion of some modern engineers, that if all the works were of the same height, it would be much better, than to make the inner ones so as to exceed those before them by 8, 10, or 12 feet, as is customary.

For it is evident that those high walls increase the expence prodigiously, and may be battered at a great distance ; so that before the enemy have carried their approaches near the place, all the defences are ruined ; which will not happen, if a work cannot be discovered till that which is before it is taken.

It is said that when the works exceed each other in height, the enemy can be fired at from all at them at once ; but this is of no advantage : for they may raise batteries at 300 toises distance from the place, and from thence dismount all the guns ; which being continually kept playing, will prevent the garrison from erecting new batteries ; and the guns being once dismounted, the fire of the small arms can produce no great effect against the trenches.

Instead of which I would chuse to place guns in the places of arms, and keep them there till such time that the covert way is in danger of being attacked, and then remove
them

them into the inner works, and so from one to another, till into the body of the place; for if the guns in the bastions, or counter-guards and ravelin, are not dismounted till such time the covert-way is attacked, it will be a difficult matter to get and remain in possession of it.

All the objection that can be made against low walls, is, that they are easily enfiladed by the ricochet batteries; to avoid which, the salient angles of all the works should be raised about 4 feet above the other parts, for the space of 5 or 6 toises on each side; and the rampart should likewise slope towards the place by 2 or 3 feet: this has been done by M. *Vauban* at *New Brisach*, and by M. *Coehorn* at *Bergen-op-zoom*; which being the last places that these great men have fortified, is sufficient to determine others to follow their examples.

The redoubt p in the place of arms, should be a wall of 3 feet thick only, with loop-holes, and no higher than the glacis, or rather two feet lower, so that they cannot be discovered but from the ridge of the glacis; the inside of them may be 2 or 3 feet lower than the rest of the covert-way, and so as to slope towards the ditch, that if any
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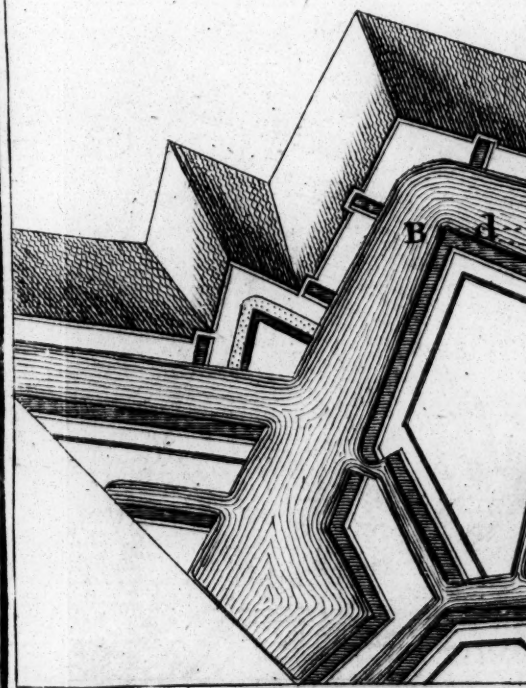
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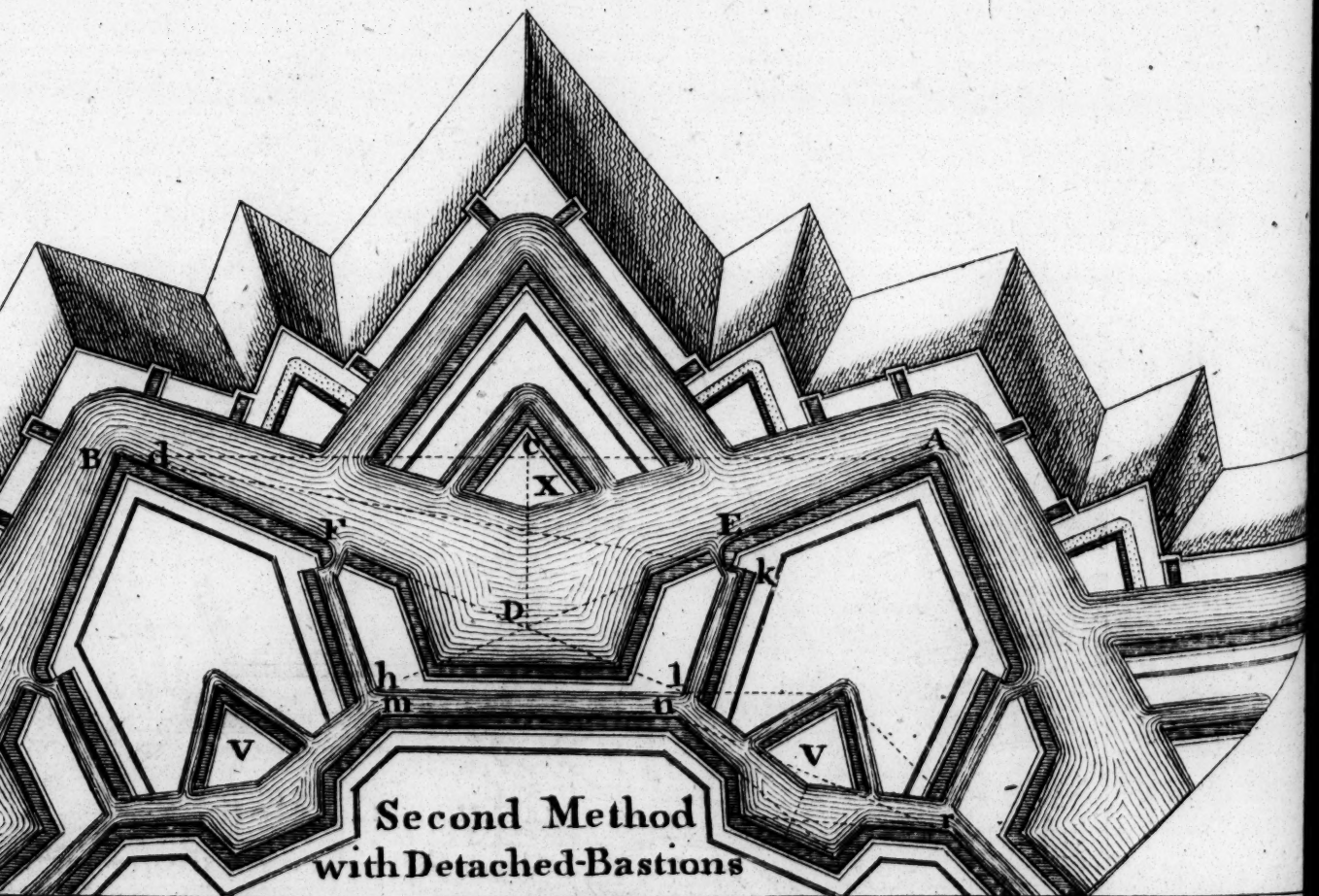


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grenades or shells should fall into them, they might roll into the ditch.

The redoubts R in the ravelin ought to have a parapet of 12 feet thick only, as being sufficient to oblige the enemy to raise a battery in the ravelin to destroy it, which is all that is wanted; they serve to retire into when the ravelin is taken, and obstruct the lodgments there; from whence the troops may retire into the body of the place, when they can hold out no longer.

As to the flanks, they are so disposed as to defend the ditch in the best manner possible, and since the detached bastions are wide and spacious, a third flank may be added, if it is thought necessary.

Construction of a place with detached Orillon Bastions.

Let the exterior side AB of an octagon Pl. XVIII. be 200 toises, the perpendicular CD 40, that is a fifth part of the exterior side, the faces AE, BF 55; the radius of the arc, which serves to determine the position of the flanks, 22; the ditch 16 at the saliant angles; the orillon 5; the flank is retired 5 toises; and the line k d, which terminates the flanks, is drawn

drawn from a point *d* in the face, at 5 toises from the saliant angle : the shoulders of the tenailles are 20 toises from those of the bastions ; the flanks parallel to the others, and the curtain is drawn through the points of intersection of the flanks and lines of defence.

Take on the lines *E l*, *F h*, drawn from the extremities of the faces parallel to the flanks, and which terminate the inside of the tenailles, the parts *l n*, *h m*, each of 6 toises, for the breadth of the ditch ; and upon the exterior side *r n*, construct a front of a polygon by making the perpendicular *i z*, and faces 20 toises.

The redoubts *V* are made of a wall 3 feet thick only, with loop-holes, their saliant angle is determined by the counterscarps of the inner ditch produced, and the faces terminate within three toises of the shoulders; the ditch about these redoubts is 4 toises.

The ravelins and covert-way are constructed in the same manner as those in the former method.

REMARKS.

This method being more expensive than the former, has the advantage in proportion; the

the ditch is defended by large double flanks, which will hold more guns than the enemy can oppose; for we suppose the body of the place and the detached bastions to be but 3 feet higher than the glacis, that is, 10 feet above the level; so that the flanks cannot be discovered but from the ridge of the glacis; the redoubts V are of special use to retire into when the detached bastions are taken, and to obstruct the lodgments there; and as the communication from these redoubts into the body of the place cannot be seen from any part, this safe retreat is of great advantage; for by this means the troops will be able to maintain their ground to the last extremities; neither can the flanks of the inner front be discovered but from the level ground of the tenailles, which therefore I would make but a foot above the water in the ditch, so that there will not be a sufficient quantity of earth to raise a battery.

If the flanks and faces of the tenailles were arched and open behind, it would be much better, for by that means the enfilading them would be impossible, neither would the shells have any effect upon them; and then the upper flanks might be made two or three feet lower than the faces, which

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would

would prevent the enfilading them by the ricochet batteries; but if this should be thought too expensive, I would make the upper flank 7 feet above the level, that is, 2 feet lower than the faces, and the lower one 3 feet above the level; but then the faces of the tenailles must be 4 feet higher than the flanks, to cover them from the enfilades: for it is of the greatest importance to prevent the enfilading the works as much as possible, since it is much more dangerous than to be seen in the front, and it is too dangerous to defend such a work: this and the securing the retreats from one work into another, are the two greatest advantages to be gained in a good fortification; and for which the stone redoubts in the places of arms, in the detached bastions, and those in the ravelins, are all that can be done; for when those works can be no longer defended, the besieged watch their opportunity in the dark, or when the enemy's fire slackens, to cross the ditch and retire; for it would be imprudent to defend them to the last; and there should be mines to blow them up, when they can be of no further use.

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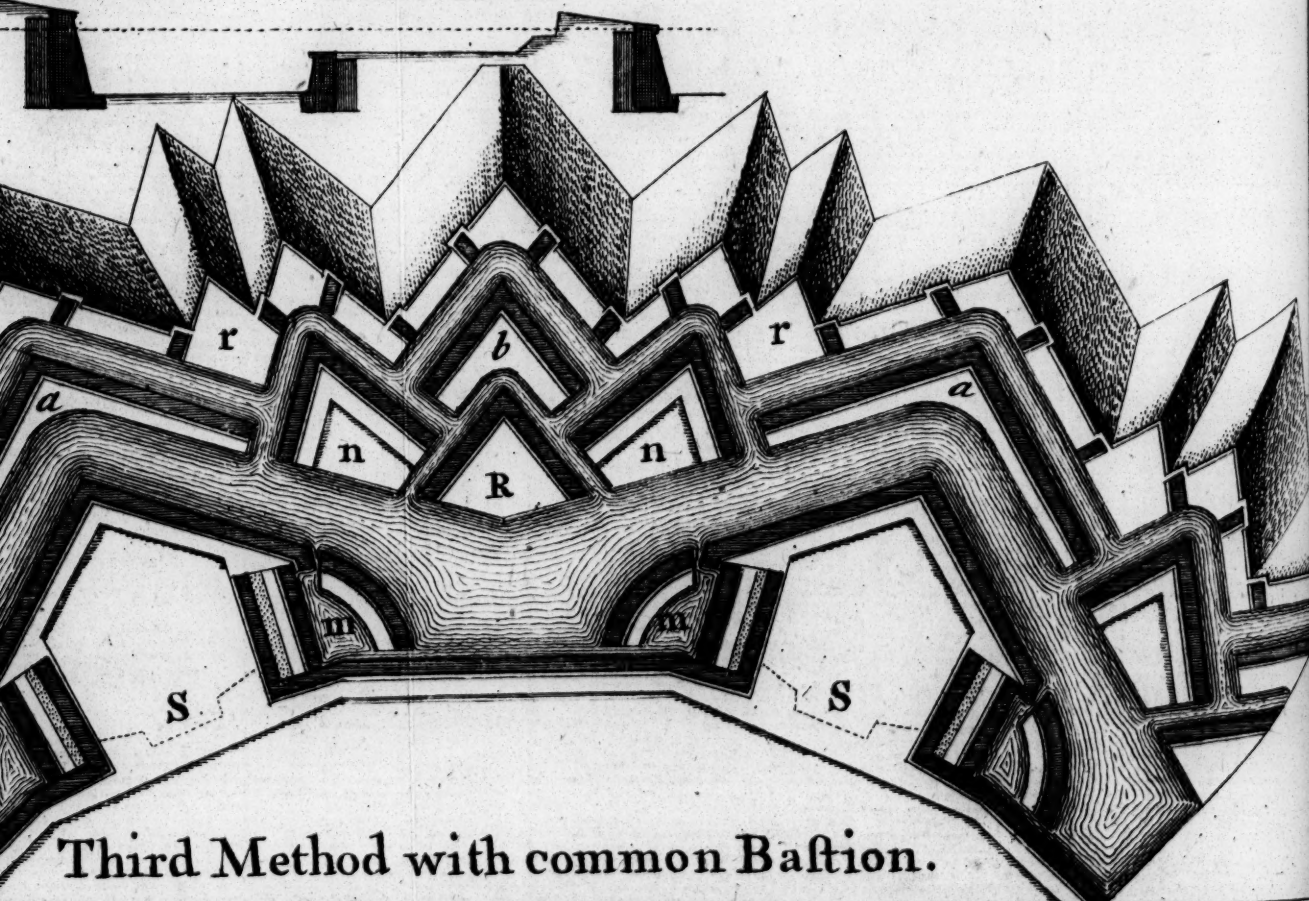
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Counterguard

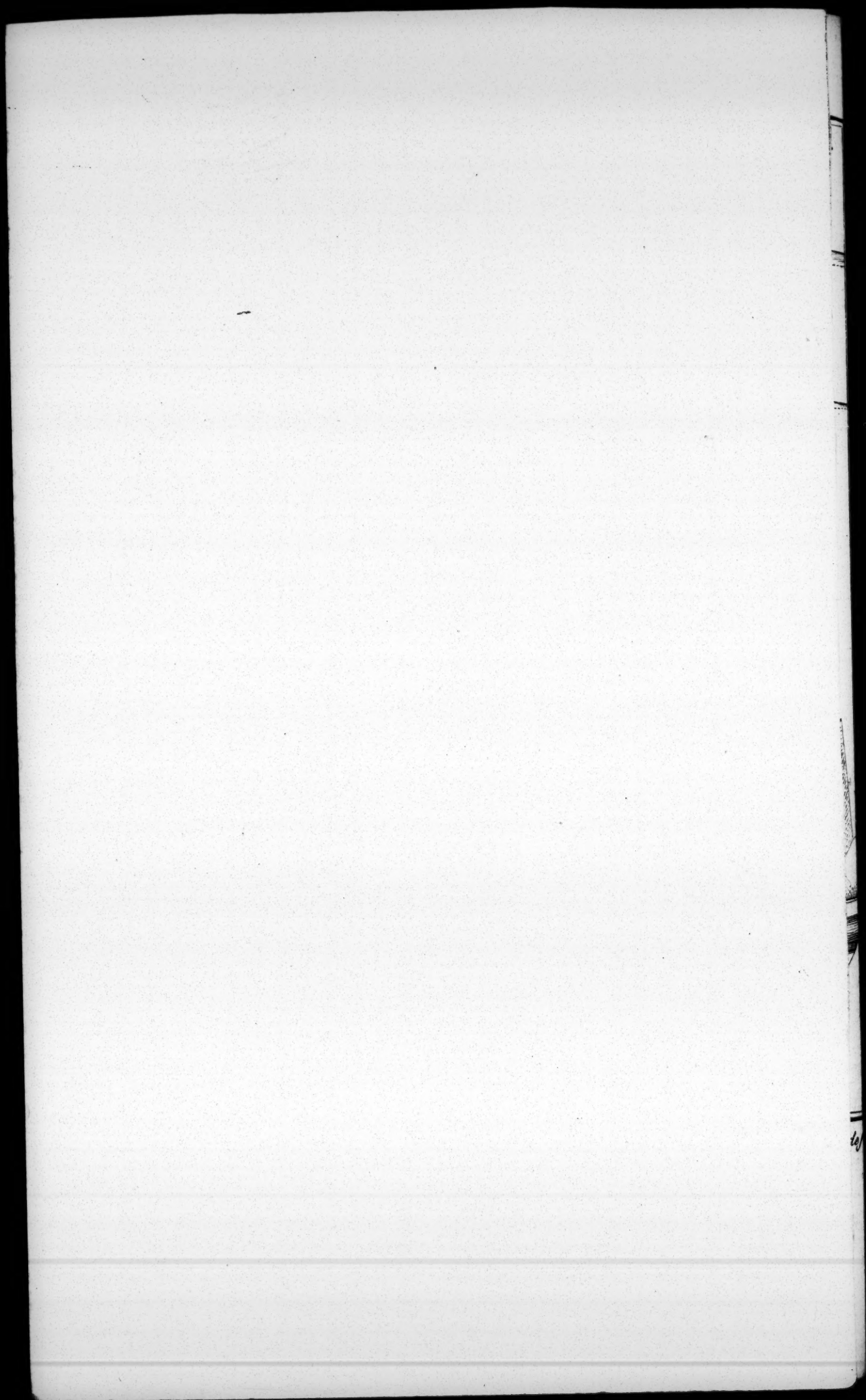
Bonnet

er Flank

Rams-Horn



Third Method with common Bastion.



*Construction of a Place with Lunettes
and Counterguards.*

This figure is an octagon, whose exterior Pl. XIX.
side is 200 toises, the perpendicular 30, and
the faces 55; the radius of the arc which
terminates the position of the flanks is 20
toises, the orillons are 5; the first flank is 5
toises retired, and the second 10 from outline
to outline; the rampart of the lower flank
is 4, and the ditch behind it 3; the faces are
4 feet higher at the saliant angles, and three
at the shoulders, than the flanks and curtain,
and that excess should be of turf: the ditch
is drawn from the extremities of the orillon
parallel to the line which serves to determine
the position of the flanks; the tenailles, or
rams-horns m, are described from the point
of intersection, of the line of defence pro-
duced, and a perpendicular to the faces pro-
duced 3 toises; and they are terminated by
a line 3 toises distance from, and drawn pa-
rallel to the curtains.

The semi-gorges of the ravelins R are
20 toises, their capitals 30, and the ditch
before them 6.

The semi-gorges of the lunettes n, the
one is 15, and the other 30 toises; and the

faces are drawn perpendicular to those of the ravelin and the bastions, the ditches before them are 8 toises.

The countersguards *a* are 7 toises broad at their extremities, and the faces perpendicular to those of the lunettes, or parallel to those of the bastions : the ditch before them is 10 toises.

The bonnet *b* before the ravelin is 10 toises broad at the ends, and its faces are parallel to those of the ravelin, or perpendicular to those of the lunette : the ditch before this work is 10, the covert way 6, and the glacis 20 ; the places of arms *r*, are found by setting off 20 toises one way, and the perpendicular drawn through that point, meeting the face of the lunettes produced.

Remarks on this construction.

As all the defences of this place are direct, that of a ravelin excepted, the works will be in a condition of making as great a resistance as can be expected ; the curtain, ravelin, lunettes, and bonnet, should be all of the same height ; as likewise the countersguards and bastions, so that the bastions may not be seen but from the countersguards, where

where there is not sufficient room for making batteries to destroy the flanks; the rams-horns serve to sally out into the ditch, when dry, or to harbour boats behind them when wet; their level ground should not be above 4 or 5 inches above water, or even with the bottom of the ditch when dry; and as they cannot be enfiladed from any part, their grazing fire will extremely well defend the great ditch, and that before the ravelin; as likewise the level ground of the ravelin, lunettes, and counterguards.

The reason that the rams-horns are not continued quite to the curtain is, that the splinters from the wall may not hurt those in the rams-horns, it saves likewise some expences, and this passage may serve in a wet ditch for boats to go out and come in, and the part between the lower flank and the rams-horn serves as a safe harbour for the boats, or as a place of arms when the ditch is dry.

Although these bastions are of as great a defence as possible, yet the enemy will in time be able to ruin the flanks, and make breaches in the faces; and this being once accomplished, the garrison will be obliged to surrender, unless some other defence be

found; for which reason, good retrenchments, such as marked S, should be partly made, either at the same time that the place is built, or in time of peace, with a good strong wall and a ditch before it; as likewise with countermines under them, to prevent the enemy from blowing them up with their mines; and from the bottom of this ditch, galleries might be carried on under any part of the bastion, to blow it up, when it can be defended no longer above ground: I said that these retrenchments should only be partly made; because, there must be about 4 toises left unfinished at each end near the flanks, in order that there may be sufficient room behind the flanks to place cannon; and when the attack is once made, the parts next to the flanks, which are of no use, may then be finished, and the other afterwards, when the flanks are of no further use: by this means the bastions will be able to make as great a defence, as if they were detached.

For it is in vain to pretend that a place should make a long and stout defence, though ever so well fortified, if the governor either wants means, or does not know how to defend it; and there ought not to be a single
work

work but what should be defended inch by inch, and when the works are spacious enough to admit of retrenchments, there should be as many made as can be done : the works must not only be thus disputed above ground, but likewise under ground ; for all the parts where the enemy is likely or must make lodgments, should be countermined, in order to blow them up when they can be no longer maintained above ground.

The expence of making countermines and retrenchments is inconsiderable, in respect to that of building the fortification, and yet they may lengthen the defence considerably. It appears shameful, that as soon as a breach is made in the bastion, and often not wide enough to waste an assault, the garrison should be obliged to capitulate ; it seems that the bastions, which are the most considerable part of a fortification, and cost most, should serve more as a shew than as a real additional strength to the place ; this is undoubtedly owing to the incapacity or slothfulness of governors, who think more by what means to make most money of their places, than how or in what manner the town is to be defended, and to provide in time against the dangers which may happen in an attack.

That a town may make a considerable defence, though moderately fortified, is no romantic fancy, as evidently appears by the sieges of *Vienna* and *Candia*, when they were attacked by the *Turks*; there was not a foot of ground gained by the besiegers, which the besieged did not immediately cut off; the former made a defence of near three months till it was relieved, and would have continued so to the last inch of ground of the whole town, if it had not, and the latter held out ten years.

In order to form a better judgment of these three new constructions, we have added the profiles of the several works, and which are nearly the same as those the *French* made use of in some of the last places they have fortified. Though we have used the octagonal polygon here, yet the same works will do in any other above an exagon with some very few variations in respect to the direct defence.

Construction of M. BELIDOR's first method.

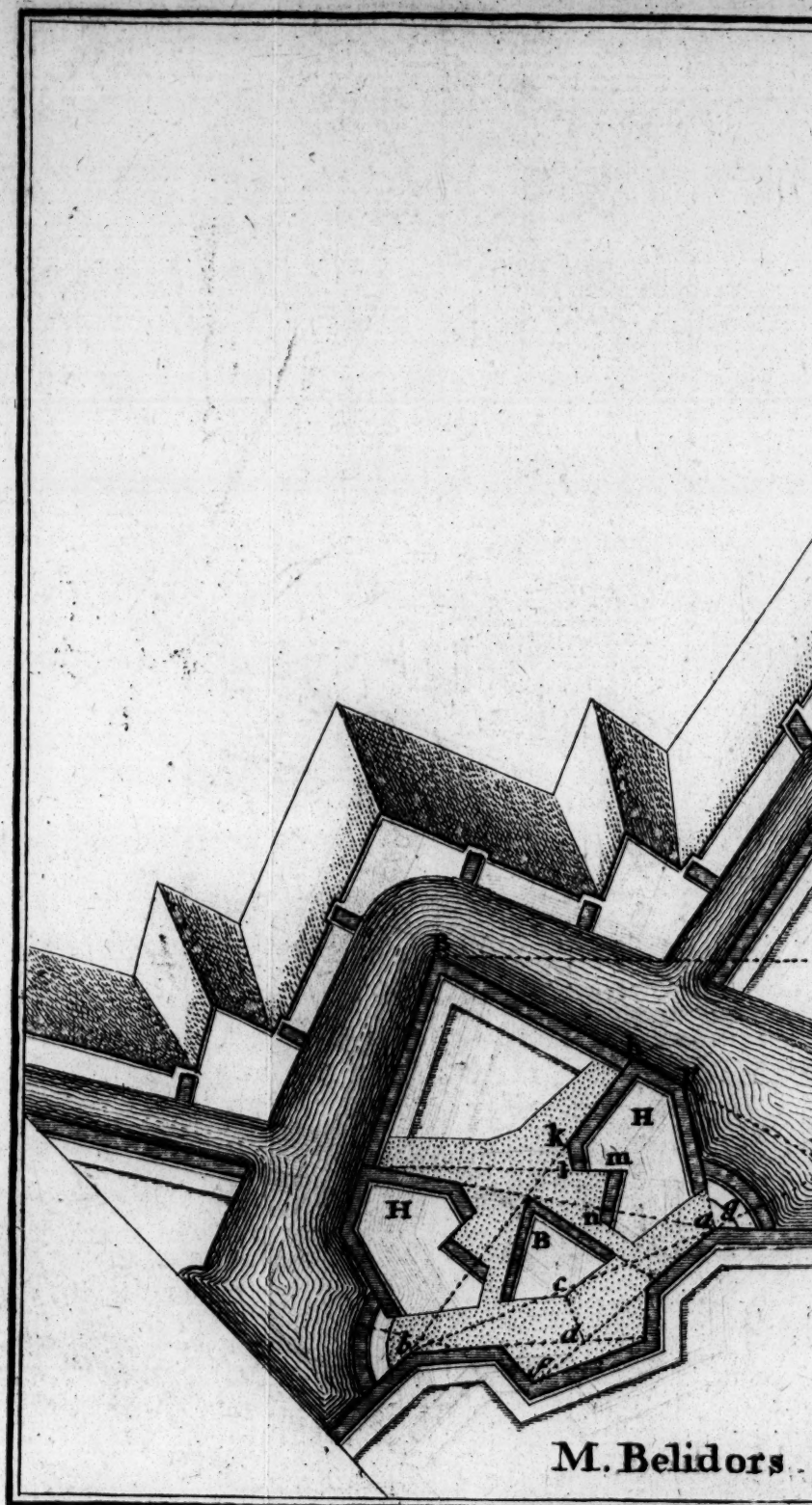
Plate XX. This figure is a part of an octagon, whose exterior side A B is 200 toises; the perpendicular

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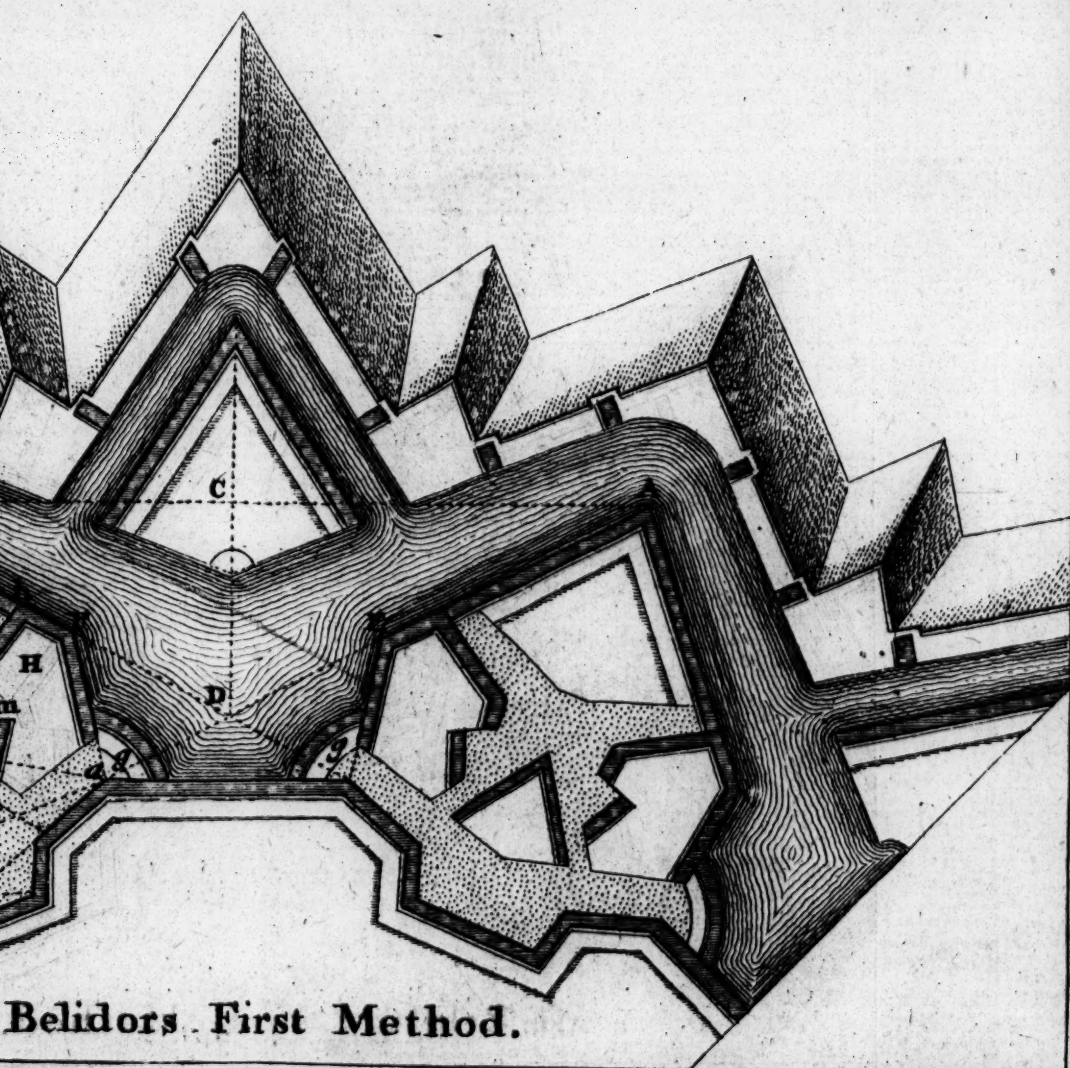
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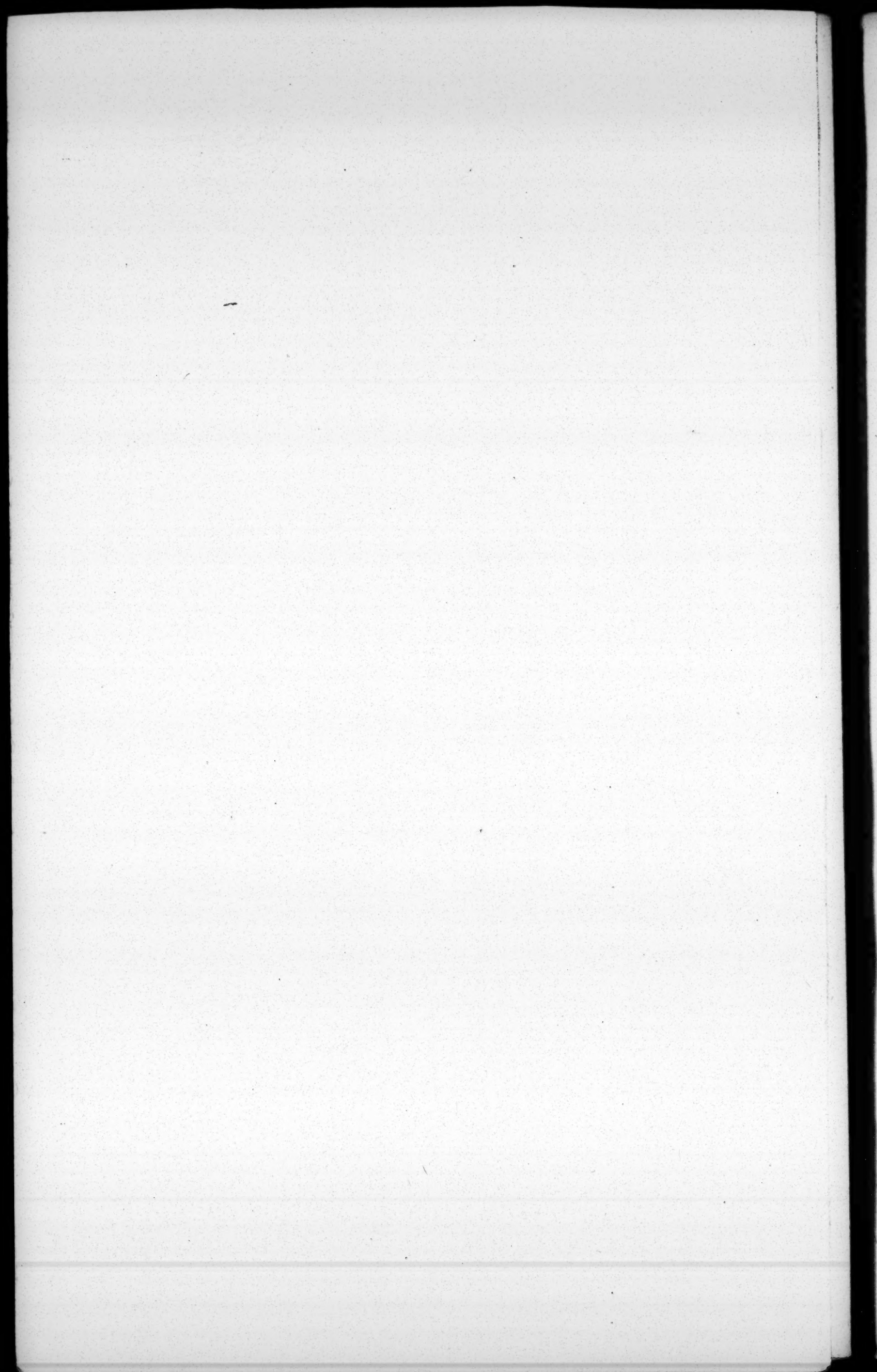
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dicular CD, 50 ; the faces AE, BF, 70 ; and the flanks are found according to M. *Vauban's* method.

The line joining the extremities *a* and *b* of the flanks of the same bastion, serves as an exterior side to trace the front of a polygon ; whose perpendicular *cd* is 13 toises, the faces 22 : the parts *df* of the lines of defence, which terminate the flanks, are 14 ; the dry ditch before this front is 10 toises at the points *a*, *b*, and the counterscarp terminates at the opposite shoulders.

The rams-horns *g*, are described from a point, in the middle of the faces of the interior front, as centers, with a radius of 25 toises.

The retrenchments *H* are drawn from a point in the face, at 15 toises from the shoulder to the points *b*, *a*, and are 25 toises long ; the orillons *k l*, 8, and the flanks *n m* are 8 toises retired near the orillon, which are the chords of an arc from the opposite shoulders ; the ditch before these retrenchments is 8 toises near the parapet of the bastions, and its counterscarp directed to the shoulders.

The salient angle of the redoubt *B* touches the intersections of the curtains produced,
and

and the faces terminate on the faces of the inner front within 3 toises of the shoulders ; its ditch is 3 toises ; these redoubts are a stone wall of 3 or 4 feet thick, with loop-holes in the faces.

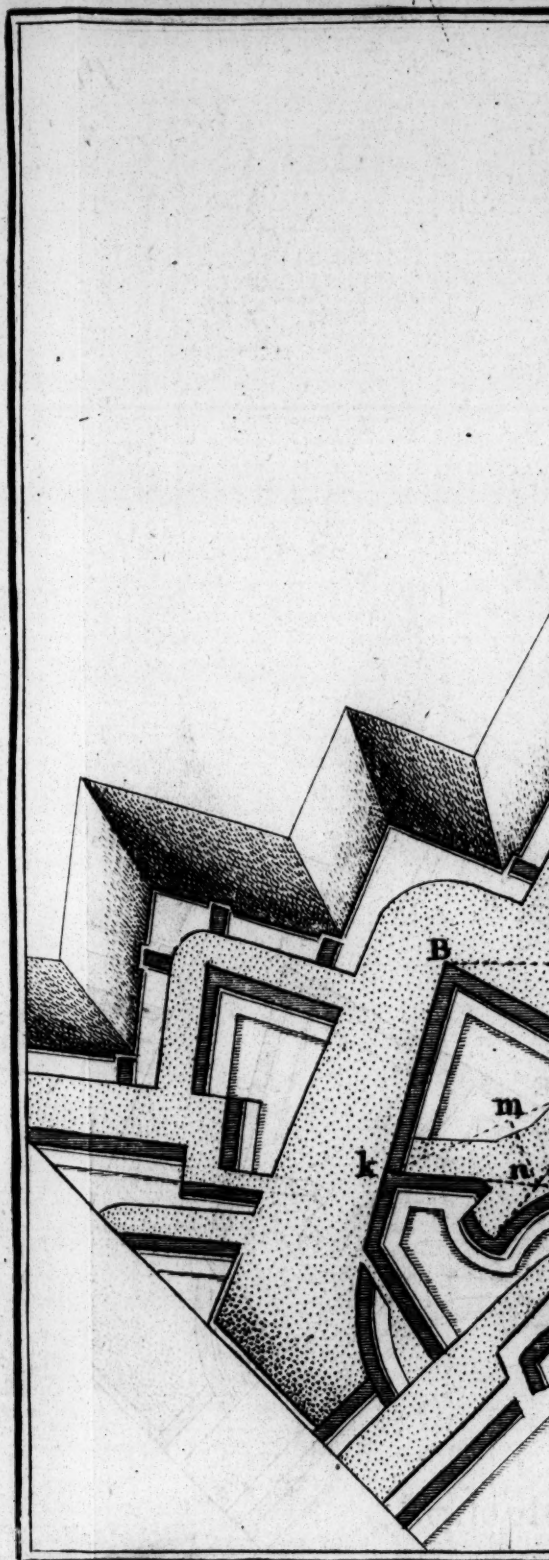
The author having made no outworks to this system, we have added ravelins and a covert way made in the usual manner ; the great ditch is twenty toises before the salient angles of the bastion, and its counterscarp is directed to the shoulders ; and the faces of the ravelins to the outline of the retrenchments H.

Remarks on this construction.

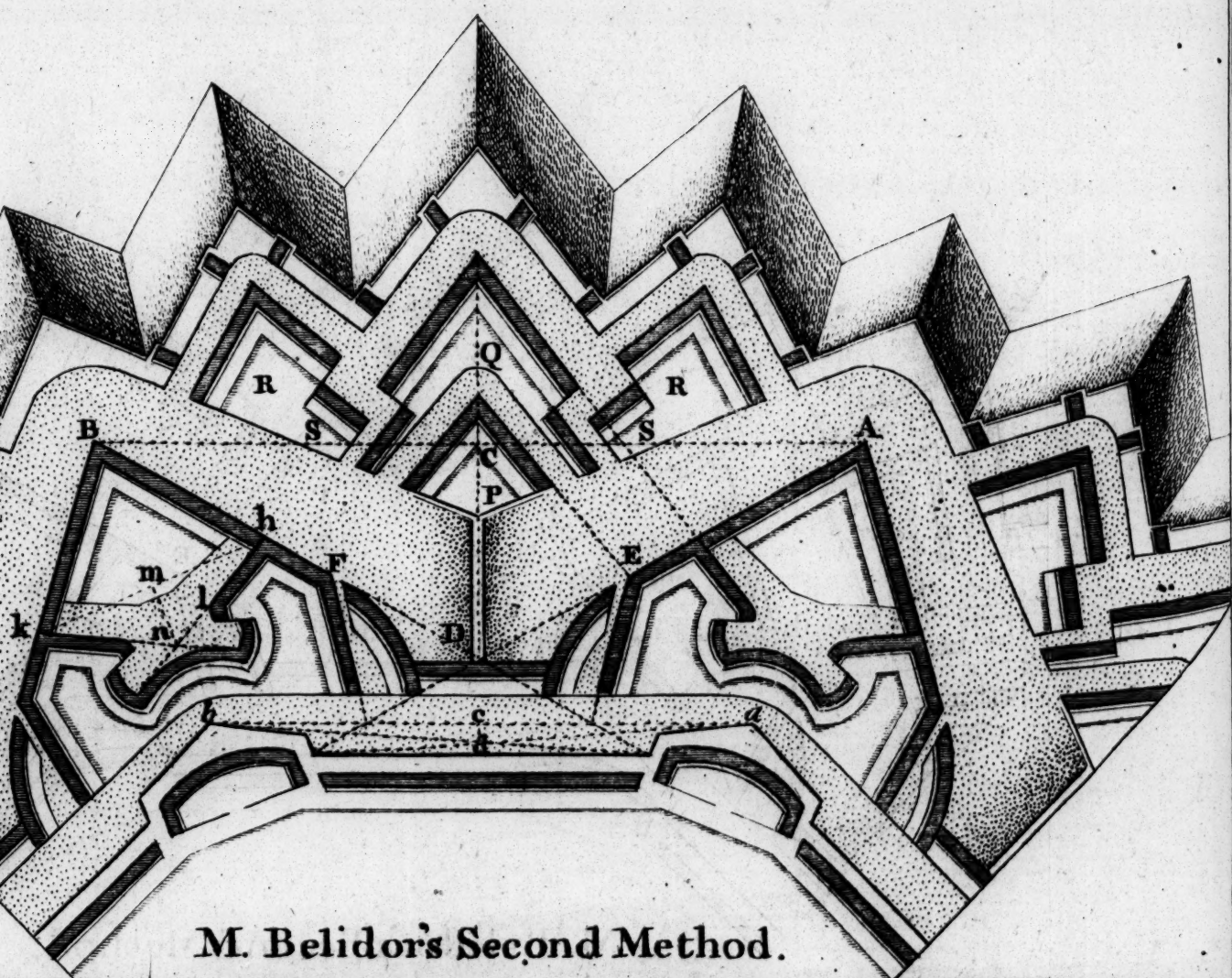
This fortification has the advantage of all those which have detached bastions ; the retrenchments within are of a good defence ; but they take up too much ground, especially the ditches, which ground might, in my opinion, be better disposed of ; besides, if the breach was made at h F, by the guns placed in the opposite place of arms and ravelin, the besiegers would find a lodgment H ready made, wanting only a part opposite to the face or the inner front. But the flanks of these large bastions, which are
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about 26 toises long, seem to be too small, and the great ditch too large; for if it was only 15 or 16 toises at the saliant angles, and the counterscarp directed to the flanks within 2 or 3 toises of the shoulders, the besieged would not find so much room to place their counter-batteries.

The ditch before the inner front might be smaller, that is, of about 5 toises; and then the flanks would become so much the longer. 8

As the ditches before the retrenchments H are directly opposite to those before the ravelin, the author designed to make a battery in them; for which he reason he carries that ditch through the parapet, and leaves only the walls to cover it; but as the enemy might soon destroy the wall, and therefore need make no other breach to enter the bastion, we have continued the parapet, and those batteries might be arched and open behind.

Construction of M. BELIDOR's second method.

This figure is again a part of an octagon, Pl. XXI. whose exterior side AB is 200 toises; the per-

perpendicular CD, 55, and the faces, AE, BF, 70, as in the former; and the flanks are likewise found according to M. *Vauban's* method.

The line *ab*, which passes through the extremities of the flanks, serves as an exterior side to the inward polygon; whose perpendicular *c d* is 5 toises, the faces 24, and the flanks are chords of arcs described from the opposite shoulders of the detached bastions as centers.

This inward polygon is nothing else but a strong wall, behind the curtain of which, and of about 18 feet distant from it, is a parapet or epaulement of earth 3 toises thick; and within the bastions are cavaliers, whose fronts are circular arcs described with a radius of about 23 or 24 toises; the flanks are 7 toises long, and gorges 32.

The counterscarp of the ditch before this polygon is 7 toises at the salient angles *a*, *b*, and parallel to the curtain.

The rams-horns or tenailles touch the lines of defence within 3 toises of the shoulders, and are described so as to meet the other lines of defence in the same point as the counterscarp of the inner ditch.

The

The outline of the curtain between the rams-horns is 9 toises from the ditch.

The exterior side $h k$ of the retrenchments within the detached bastions, meets the faces within 20 toises from the shoulders; the perpendicular $m n$ is 17, the faces $h l$, 20; the chord on which the orillon is described is 5 toises, as likewise the retired part of the flank i the flanks and orillons are made according to M. *Vauban's* method.

The circular curtain and the round part of the ditch behind it, are described with a center, 25 toises distant from the points a, b .

The great ditch is 20 toises before the salient angles of the detached bastions, and is supposed to be dry; for which reason M. *Belidor* made a caponiere to go from the curtain to the ravelin, of 18 or 20 feet wide, whose parapets terminate on both sides in a slope or glacis.

The capital of the ravelin Q is 66 toises, that of the redoubt P , 30; the faces of the ravelin are directed to those of the retrenchments within the bastion, and those of the redoubt to the shoulders; the batteries in the ravelin are retired 8 toises behind the faces; the ditch of the ravelin is 12 toises, and that of the redoubt 7.

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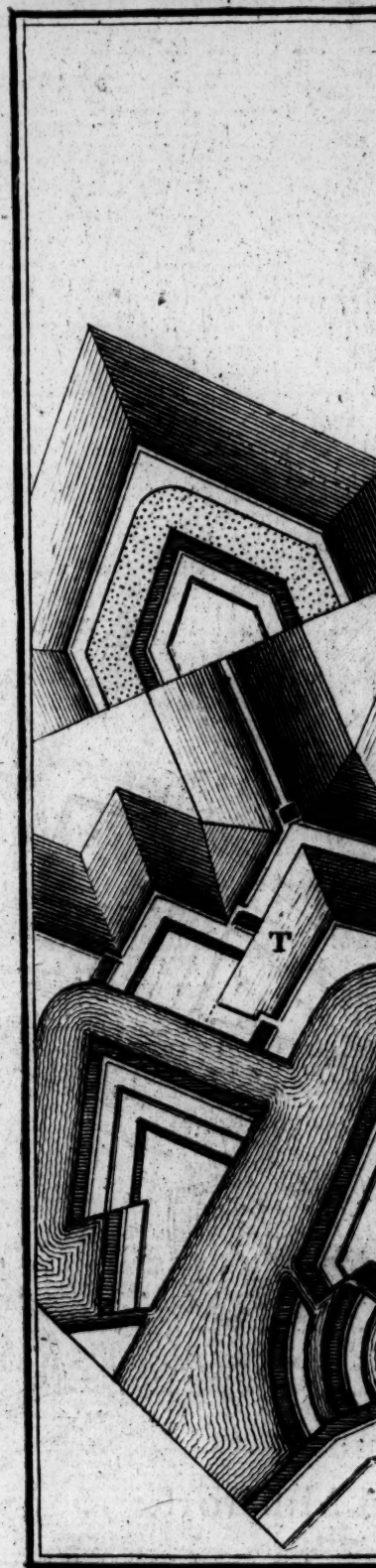
The semi-gorges of the lunettes R are 25 toises, and the faces perpendicular to those of the ravelin and the bastion; the ditch before them is 8 toises, and the batteries S are retired as much, and are 15 toises long: lastly, the covert-way is 6 toises.

Remark on this construction.

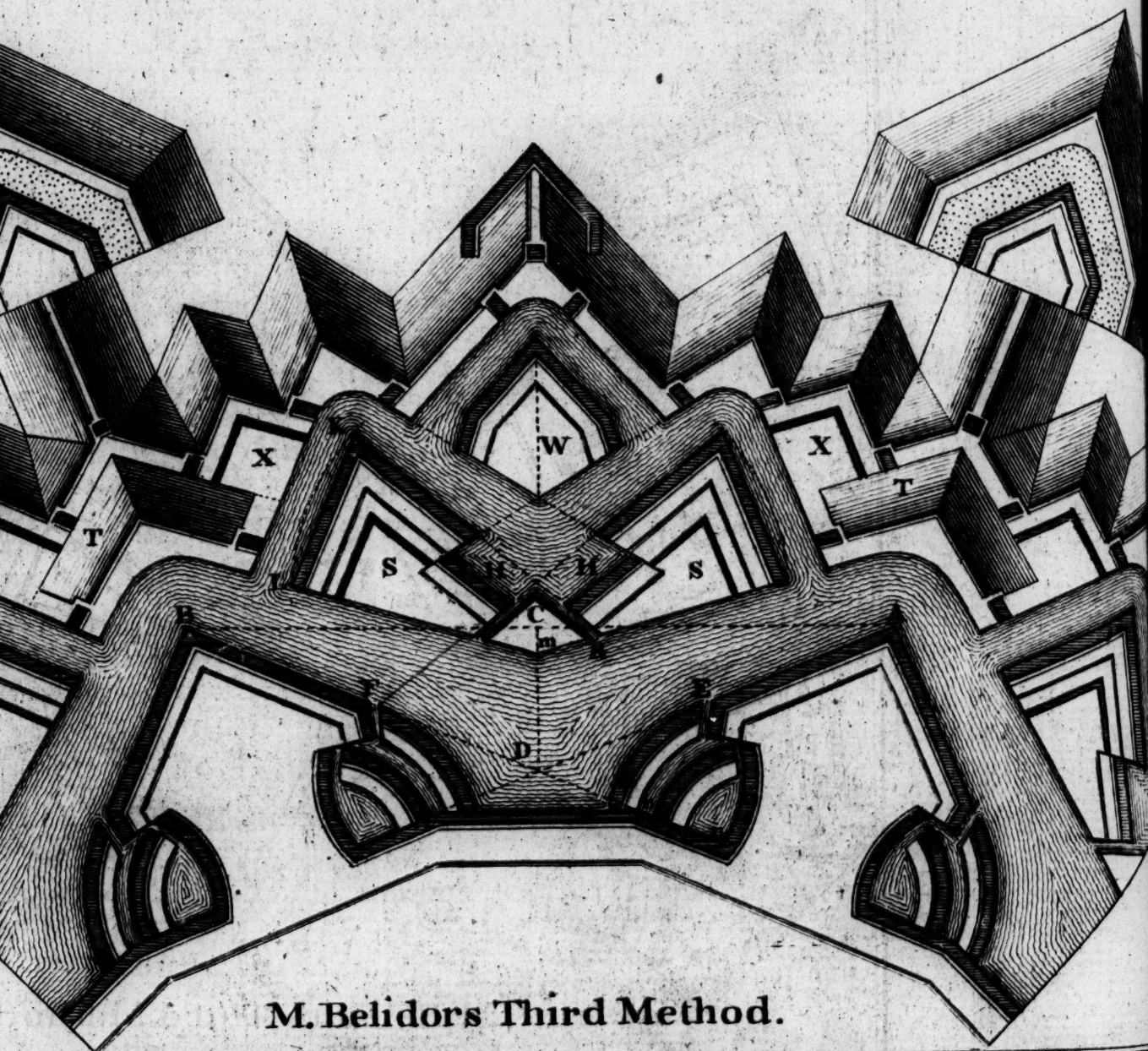
If the parapet behind the curtains, and the cavaliers in the bastions, of the body of the place had been joined to the wall, it would have been much better, since the wall will soon be destroyed, and thereby open the place at once: the perpendicular of the great polygon is a great deal too long, it makes the bastions too big and expensive; the great ditch is likewise too wide; the earth taken out of it will be more than is required for raising the ramparts. As to the outworks, they seem to be extreamly well disposed, and capable of a good defence, excepting the retired batteries in the ravelin Q are, for the greatest part, covered by those of the lunettes R; for which reason, lunettes disposed in the manner represented in the 19th plate are, in my opinion, of a much better defence than these here; but the whole

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M. Belidors Third Method.

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whole work together is too expensive to be ever made use of; for it would require almost a whole army to defend these works, and if we consider the prodigious quantity of stores and ammunition required, one may easily perceive that this fortification will never be used.

Construction of M. BELIDOR's third method.

This figure is likewise a part of an octa- PI. XXII. gon, whose exterior side AB is 200 toises, the perpendicular CD, 40; the faces AE, BF, 55; the parts Dr of the lines of defence, between the perpendicular and the broken part of the curtain, 30; and the length of the broken parts rn, 25; the orillon is 9, and is part of a flank found according to M. *Vauban's* method; the flanks are 8 toises retired, and are arcs of 60 degrees; the outlines of the rams-horns are 13 toises distant from each other; the passages at their extremities are 3, the outmost or lowest is described with a radius of 30 toises, and the other is described from the same center.

We

We have omitted the cavaliers placed in the gorges of the bastions, as being according to our notion superfluous.

The center R of the arc KL is 18 toises distant from the re-entring angle of the counterscarp ; the chord KL is 44 toises, as well as the other face of the lunette ; and the radius RK, 88 ; the battery H is 10 toises retired.

The figure m is a redoubt made of a stone wall full of loop-holes, with a ditch of 2 toises before it.

The ditch before the lunettes is 12 toises at the saliant angles, and its counterscap directed to the extremities of the opposite faces.

The capital of the ravelin W is 44 toises, the semi-gorges 31 ; the flanks are 9 toises, and directed to the shoulders of the bastions.

The ditch before the ravelin is 10 toises, and the covert-way 6.

The glacis T, before the saliant angles of the bastions, is 15 toises broad ; the semi-gorges of the places of arms X are 26 toises ; and those of the redoubts, or stone wall within them, 20, reckoning from the edge of the glacis T ; and the faces are drawn parallel to the opposite semi-gorges.

The redoubts S within the lunettes, are also made of a wall 3 or 4 feet thick, full

of loop holes, with a ditch of 3 toises before them.

The dimensions of the arrows and detached redoubts, are the same as those in M. *Vauban's* methods, only the arrows have flanks parallel to the passage of 10 toises.

Remarks on this construction.

M. *Belidor* commits the same faults in all his works, as almost all those who fortify upon paper only; by considering how a place might be strongly fortified, without troubling themselves about the expences of building, or the great number of troops to defend it; imagining, I suppose, that a Prince or State, should spare no expence to secure the subjects against a powerful enemy. If it were only for the expence of building them, I should be of their opinion; but when it is considered how much artillery and ammunition is required, together with the great number of troops to defend such places, it may easily be conceived, that their first notions must necessarily vanish into smoke.

But let us enter into particulars; the redoubts are intended to secure a safe retreat from the lunettes when they are taken;

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but

but as the besiegers may easily destroy them with the same guns placed in the opposite ravelin, which serve to batter the faces of the lunettes, as likewise the curtain of the body of the place, they will hardly answer the purpose for which they were designed; he should have added a parapet of 12 or 15 feet, which would have effectually secured the retreat. The lunettes might have been constructed so as to defend each other directly, as likewise to be defended directly by the opposite faces of the bastions; and if there had been made counterscarps instead of the glacis T, they would have covered the bastions and the opposite flanks, and would not be liable to be taken sword in hand, as these works may be taken. I suppose the author intended to secure them with pallisades, but when the pallisades are higher than the glacis, the besiegers guns will soon destroy them, and make their defence more dangerous than useful; if they are equal in height with the glacis, and placed near the parapet, the enemy jumps over them; and if they are farther off, they are troublesome, and easily destroyed by the ricochet batteries; from whence it may be concluded, that these works are of little or no defence.

The

The places of arms are too spacious, and the counterscarp of the ditches before the detached redoubts being parallel to the flanks, render the ditch before the faces defenceless, and therefore serve as retrenchments ready to receive the enemy, without requiring so much as a traverse to cover them; the flanks of the arrows are made with no more judgment than these ditches.

The rams-horns are certainly very well contrived; they are much preferable to the *tenailles*; they cannot be enfiladed from any one place, resist better, by their bending outwards, the enemy's batteries, and render the flanks much superior to any battery that the enemy can raise against them; but the retired flanks have the same defect as those of M. *Vauban's*, which we have shewn before: it is surprising, that no author has ever observed the badness of these kinds of flanks; the great character which M. *Vauban* has justly acquired, has probably imposed upon their understandings. The stone redoubts S, and X, in the lunettes and places of arms, are undoubtedly very good, they add much strength to those places, and secure a retreat to the troops which defend them.

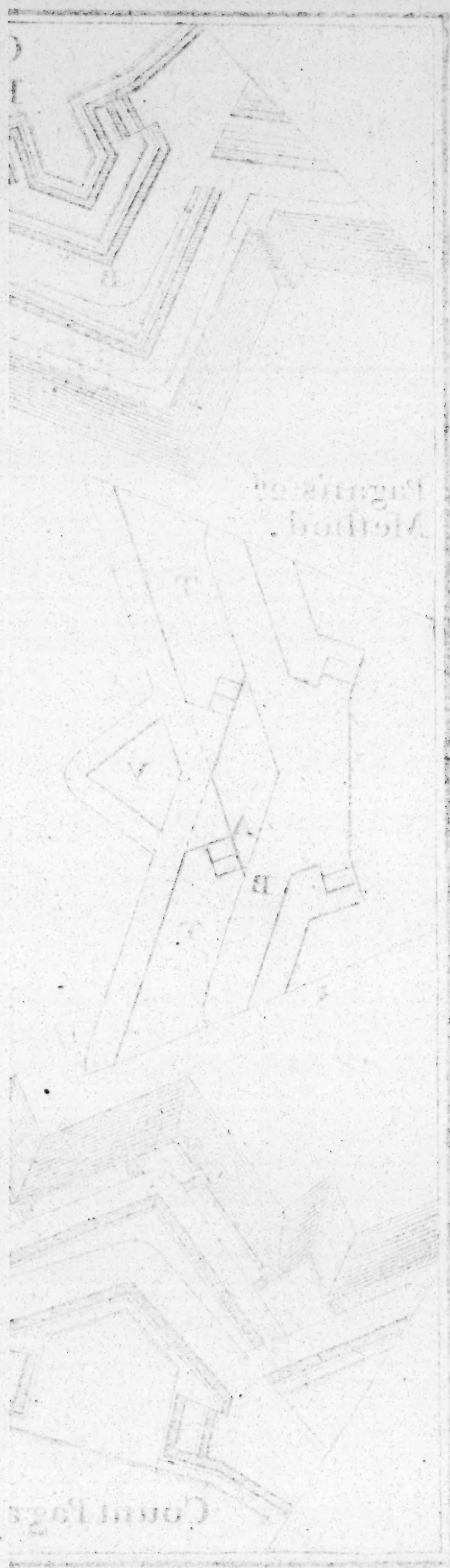
*Construction of M. BLONDEL'S
method.*

PL. XXIII. M. *Blondel* establishes two sorts of fortifications, *viz.* the great, whose exterior side he makes 200 toises, and that of the little 170; he begins with the angle made by the exterior sides and the lines of defences, for which he observes the following rules.

Subtract 90 degrees from the angle of the polygon, and take the third part of the remainder, to which add 15 degrees, and the sum will be the angle sought. For example, in an exagon, the angle of the polygon is 120 degrees; from which take 90, and there remains 30, the third part of which is 15; this added to 10, gives 25 for the angle required.

He makes likewise his lines of defence equal to $\frac{7}{10}$ of the exterior side; that is, 119 or 120 in the little, and 140 in the great; this being premised, the construction is as follows.

Let the exterior side AB of an exagon be 170 toises; the angles ABC, BAD, 25 degrees each; the lines of defence AD, BC, 120 toises; let O be the point of intersection



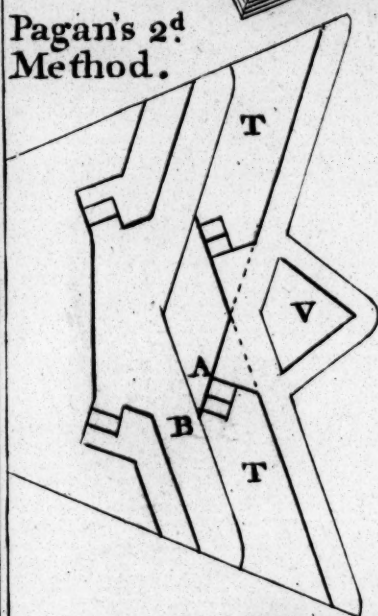
Pagan's 2d Method.

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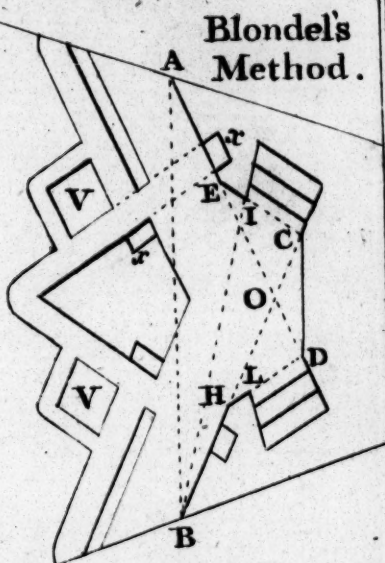
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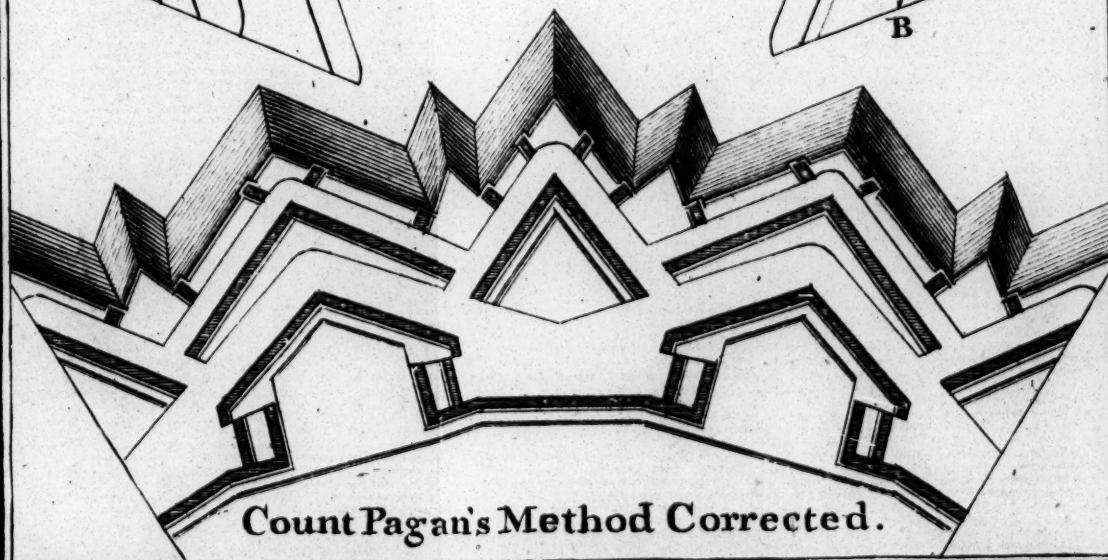
Pagan's 2^d
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Blondel's
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Count Pagan's Method Corrected.



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section of these lines, bisect AO, BO in E and H; then will AE, BH be the faces, EC, HD the flanks, and CD the straight part of the curtain.

The orillons EI, LH, are 10 toises each, the flanks are retired 5 toises behind the lines EC, HD; in all ploygons above an eptagon, he makes the retired flanks from 10 to 12 toises distant from these lines, in order to lengthen the curtains,

Each flank exceeds the flank before it 9 feet in height, and they are 8 toises distant from outline to outline.

The counterscarp of the ditch is drawn from the extremities I, L of the orillons, parallel to the faces of the bastions: the countersguards are but 4 toises broad, 10 or 12 feet of which are taken for the parapet; the ditch before them is 10 toises.

If from the shoulder E, as center, there be an arc described through the shoulder H, and from H through E, their intersection will be in the saliant angle of the ravelin, the faces of which are directed to a point in the faces of the bastions within 6 toises of the shoulders; the gorge of the ravelin is determined, by producing the faces of the countersguards; the ditch of the ravelin is 12 toises.

The semi-gorges of the lunettes V, are 20 toises : the faces are parallel to the counterscarps of the ditches, before the ravelin and counterguard, and the ditch before them, is 8 toises ; the covert-way 6, and the faces of the places of arms, which are likewise parallel to the counterscarps, are as much.

The retired batteries α , in the bastions and ravelins, are 7 toises from the faces ; and their lengths are determined by the faces and counterscarps produced of the ravelin and counterguards.

Remarks on this construction.

M. *Blondel* was undoubtedly a great man in his time, and had travelled all over *Europe* and *America*, where he made very good observations of all the different manners of fortifying, by the several nations, as appears by his small treatise on fortifications.

Notwithstanding his great skill in discovering the faults committed by others, and endeavouring to avoid them, yet he fell into others of much more consequence ; neither did he consider the great expence his method

must cost, (which is the case of most authors) and likewise the numerous artillery required to defend it.

However, if the works were of good defence, he might be excused in neglecting the expence; but how far he has succeeded in that respect, we shall make appear.

He imagines, that places are generally lost for want of having sufficient flanks, for which reason he makes three, one behind another; but they are too near each other, so that the rubbish of the upper flank must certainly destroy the use of the lower: besides, if any shells fall into the lower ones, they must inevitably destroy the troops that are there, as not having room enough to avoid them; they are likewise too open, and so more liable to being destroyed from the covert-way, for the counterguards are not broad enough to screen those flanks, as the author imagines; since a few mines will soon destroy them, as we have observed in M. Coeborn's method, who made his after M. Blondel.

The low batteries α , are likewise too narrow and too much confined; though they might have been of good defence, before the shells were so much used, which was

perhaps the case, when this method was invented.

Had M. *Blondel* known the use of ricochet batteries, he certainly would not have omitted the traverses in the covert-way as he does; his places of arms are too small to make any tolerable defence.

His great ditch is too wide by much, for it is at least 25 toises before the faces of the bastions; for the expence of removing the great quantity of earth out to them, to a great distance, is both idle and needless.

Construction of Count PAGAN's method.

This author establishes three sorts of fortifications, *viz.* the great, mean, and little, whose principal dimensions are contained in the following table.

TABLE.

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TABLE.

	Great Fortification.		Mean.		Little.	
	Square	In all the other Pol.	Square	In all the other Pol.	Square	In all the other Pol.
Exter. Sides.	200	200	180	180	160	160
Perpendic.	27	30	24	30	21	30
Faces.	60	60	55	55	45	50

Let the exterior side AB of an octagon be 180 toises, the perpendicular 30, and the faces 55; draw the flanks perpendicular to the line of defence, which bisect by a line drawn from the opposite salient angles; the one half serves for the orillon, the first flank

PL. XXIII.

THE ELEMENTS

flank is 5 toises retired behind the orillon, the others are 7 toises distant from outline to outline; the faces of the cavaliers in the bastions are parallel to those of the bastions, and 13 toises distant from them.

The great ditch is 16 toises, and its counterscarp parallel to the faces of the bastions; the capital of the ravelin 50, and its faces are drawn to the shoulders; the semi-gorges of the redoubt within the ravelin 15, and the faces parallel to those of the ravelin; the ditch of the ravelin 12, and that of the redoubt 6; the salient angle of the counterguard is 40 toises distant from that of the bastion, and 9 or 10 broad at the extremities; the ditch before the counterguard is 12, which is the same as that before the ravelin; the covert-way 4, and the faces of the places of arms 8, and are parallel to the opposite counterscarp.

The author makes other outworks, as in his second method, where the counterguards T are 25 toises broad; they are joined by a crooked curtain, taken in the faces produced; the distance AB between the inward and outward flank is 17 toises, and divided into three equal parts, for the
three

three flanks; the capital of the ravelin V, is here but 35 toises, and the faces directed to the shoulders of the counterscarps; the ditch before the ravelin is 9, the rest is the same as in the first construction.

All the ramparts are 7 toises broad, out of which 3 are taken for the thickness of the parapets; in the square the lower flank is taken in the same line with the orillon, but in all the rest they are 5 toises retired behind it.

The flanks exceed each other 12 feet in height; the great ditch is 18 deep, and the body of the place is 36 high, taken from the bottom of the ditch; the ditches of the ravelins and counterscarps are 12 deep; and their ramparts are 24 high from the bottom of the ditch; so that the height of the body of the place exceeds that of the outworks but by 6 feet.

The great advantage that this method had above all those which appeared then, has gained the author a great reputation, and his first system has been used in several places; and though this is the only author who has given the true position to his flanks, yet he has been found fault with on that very account, as being too much exposed, and too easily ruined by the enemy's counter-batteries,

ries; most authors take it for a general maxim that the direct defence is the best, and we have proved it in the beginning of this section; and yet a late *French* author, who takes *M. Vauban* to be his hero, says, *that if they were not so direct, they would be no less good, and it is not necessary here to observe a geometrical exactness*; but how this author reconciles his manner of arguing with the above-mentioned general maxim, is a thing I do not understand; for if this maxim is not to be followed, it should not be mentioned: and if exceptions are to be made in certain cases, it is not general.

This author blames likewise Count *Pagan* for making his orillons equal to half his flanks; by which means he says, there is so much of the flanks lost, and a lesser orillon would have been sufficient: in which he is mistaken, for there may be 4 guns placed upon the orillon; and if the Count made his retired flanks but half the straight flanks, it is because he thought that there is room enough to place as many guns in them as are necessary to defend the ditch; and by doing so, they were better hid, and not so easily dismounted by the besiegers: it is certain, that his flanks are too near one another, and if there

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there were but two in polygons under an octagon, it would have been much better; the ditch before the redoubt is but ill defended, which should never be made without making tenailles likewise; so that it might be defended from thence.

We have said that his ramparts are but 7 toises in general, so that the parapet, which is 3, being taken from 7, there remains but 4 toises or 24 feet for the free passage and batteries, which is too little; because the platforms take up 18 or 20 feet, so that there remains not room enough to pass by with another carriage. M. *Vauban* made the level ground of his ramparts 30 feet, and sometimes more, in most places he fortified, though in his construction but 4 toises or 24 feet; but as he never published any thing himself, those that have given his works to the public have, I suppose, substituted their own dimensions.

His covert-way seems to be too narrow, and the places of arms too inconsiderable, for defending the glacis; the not making traverses in the covert-way, is likewise a great mistake; but as the ricochet batteries were not known in his time, there was not yet so much occasion for them then, as there is now.

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The counterguards in his second method are too spacious; his proposing to build hospitals, store-houses and magazines in them, must prove a great detriment to their defence, unless those buildings are demolished when these works are attacked.

Count PAGAN's method corrected.

The exterior side of this octagon is 200 toises, the perpendicular 30, the faces 60, the orillon 5; the first or lowest flank is 4 toises retired behind the orillon, the flanks are 12 toises distant from outline to outline; the great ditch is drawn from the extremities of the orillons, parallel to the faces of the bastions; the ravelins are made in the manner described in plate XV.

The salient angle of the counterguards is 35 toises distant from that of the bastions, and they are 8 toises broad at their extremities, the ditch 12; there should be retrenchments made in the counterguards, perpendicular to the middle of the faces, with a ditch before them of 3 or 4 toises.

The covert-way is 6 toises, the semi-gorges of the places of arms 20, and the faces are perpendicular to the counterscarps.

Remarks

Remarks on this construction.

All the works in this fortification have a very good defence; the compactness of the works, and the little expence, in respect to the extent of the town, makes this method far preferable to any other.

For we suppose the town wall no higher than the counterguards and ravelins, so that a line drawn from the inside of the parapet of the body to the extremity of the glacis, determines the heights of the counterguards, ravelin, and the ridge of the glacis.

We have made but two traverses in each branch of the covert-way, but because of their length, there may be made three, to prevent better the enfilades of the ricochet batteries; these traverses need not be so thick as they are generally made, for 10 or 12 feet would be sufficient to resist the ricochet batteries.

As the flanks are here perpendicular to the lines of defence, it was necessary to make the counterscarp of the great ditch parallel to these lines, according to what has been said with respect to the true position of the flanks, at the beginning of this section.

If

If the lower flanks were arched and open behind, in all places that have two or three, it would be much better, since this would effectually prevent the enfilading them, when they are not covered by orillons; they would likewise be out of danger from the shells, especially when there is a ditch behind, and the level ground goes sloping towards the ditch.

S E C T. III.

Of irregular Fortification.

TH E most essential principle in fortification, consists in making all the fronts of a place equally strong, so that the enemy may find no advantage in attacking either of the sides; this can happen no otherwise in a regular fortification situated in a plain or even ground; but as there are but few places which are not irregular, either in their works or situations, and the nature of the ground may be such as makes it impracticable to build them regular, without too great expence; it is so much the more necessary to
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shew in what consists the strength or weakness of a town irregularly fortified, so that the weakest part may be made stronger by additional outworks ; as likewise, if such a place is to be attacked, to know which is the strongest or weakest part.

All the authors who have wrote on fortification, that I have seen, are so deficient in regard to this, that not the least knowledge can be gathered from their writings ; they do not even mention any thing about it. From whence it seems to appear, that there can be given no general rule, whereby the strength or weakness can be discovered ; and if we consider the several attacks that were made in the late wars, one would be inclined to think, that the engineers were no ways acquainted with it. A late author has mutilated what is here said, and enlarged upon the subject very much ; he had the assurance, not to say worse, to persuade the public, that all was his own invention, as if this work had not been known before his ; but his whole performance consists in nothing else than a heap of absurdities.

That M. *Vauban* understood irregular fortification perfectly well, is plain from those places he has fortified of that kind ; and yet

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his commentators mention nothing of it; they very often lavishly bestow their praises on some of his works which do not deserve it, and are silent upon those which are very justly to be esteemed.

When the situation of a place is such that it cannot be regularly fortified, it should be contrived to make it nearly so; that is, instead of inscribing it in a circle, it should be inscribed in an oval, so that one half may be like and equal to the other half; and when this cannot be done, it should be made as regular as it possibly can be, and as much as the nature of the ground will admit of.

But to reduce irregular fortification into some form, that from thence their perfections and imperfections may be discovered; we shall suppose, in the first place, that one half; of the place is equal and like the other half; and then shall shew the application of this principle in all sorts of irregular places.

PROPOSITION.

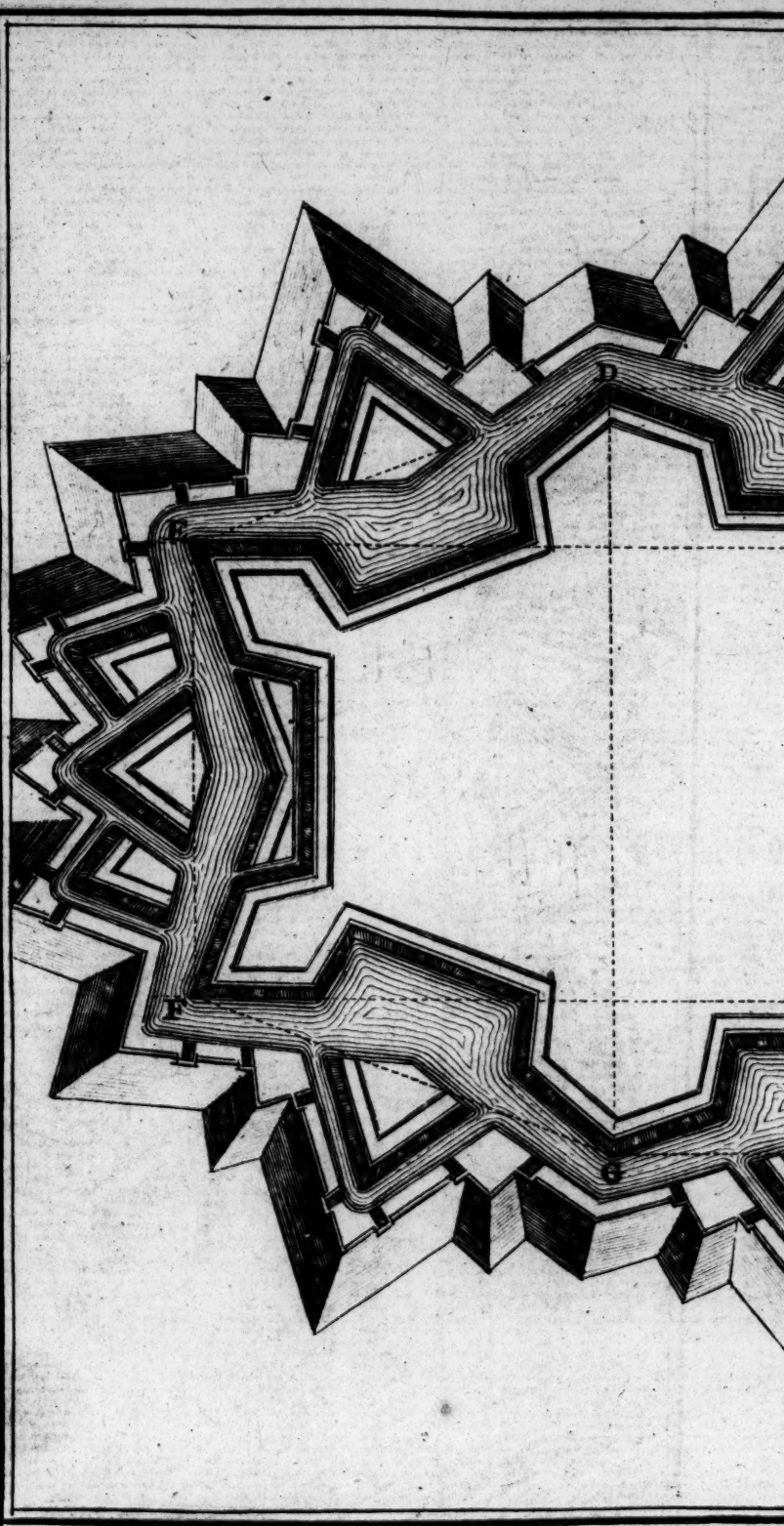
PL.XXIV. If a fortification be inscribed in an oval, that is, if the one half is equal and like the other half; I say, that the sides CD, GH,

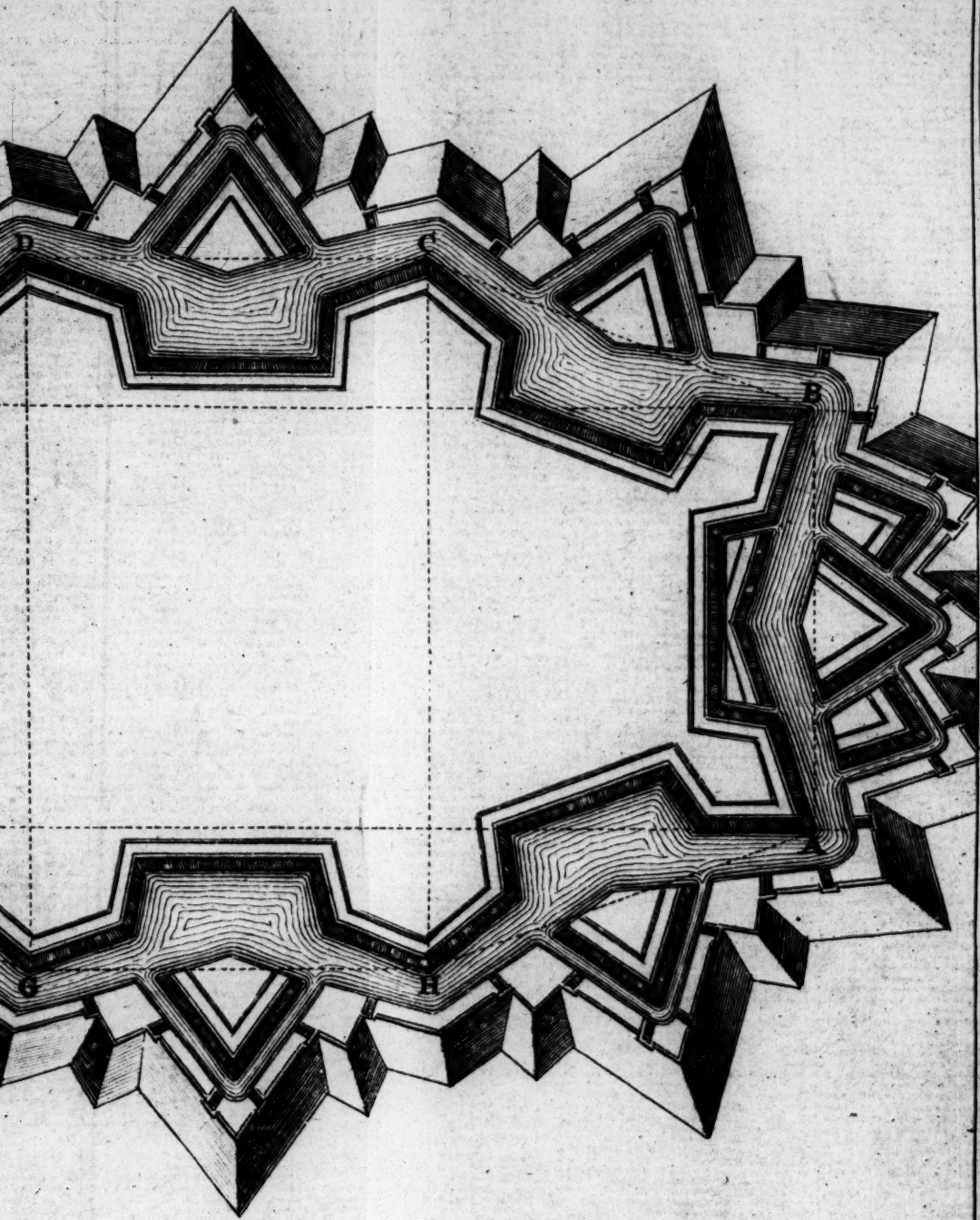
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on the flat parts, are stronger than the sides AB, EF, on the narrow parts, supposing all the exterior sides equal, and the place equally fortified.

It must be considered, that a front may be esteemed more or less strong, in proportion as the besiegers are obliged to make more or less works in their approaches; and when these approaches; are such, as being produced, shall always fall without the fortification, otherwise they may be seen in front by some of its parts; therefore when the angles BCD, CDE of the polygon are very great, and the besiegers come within a small distance of the works, they cannot approach any nearer without being seen in front, excepting by a direct sap, with traverses; and as this way of approaching presents but a small front, the besieged, who have a much larger, may oppose what obstacle they please.

And on the contrary if the angles HAB, ABC of the polygon are very small, the besiegers may carry on their approaches to the very counterscarp, and have always a larger front than the besieged.

Moreover, as the besiegers must extend their approaches to three fronts, whether

they are small or large, the work of the approaches before the front BCDE, will be to the work before the front HABC, as the line BE is to the line HC nearly ; that is, as the greater axis of the oval is to the lesser : consequently the front CD on the flat side, is stronger than the front AB on the narrow side.

COROLLARY. I.

Hence it follows, that the longer the exterior side CD of a polygon is, provided the lines of defence are within the reach of musket-shot, and the angles BCD, CDE of the polygon the same, the stronger the front will be ; since the works become more spacious, may hold more troops to defend them, and the besiegers are obliged to extend their trenches farther.

COROLLARY II.

It follows likewise, that the greater the angles of the polygon BCD, CDE are, the exterior sides being the same, the stronger the front CD will be ; because the length of the line BE increases, and the extent of
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the besiegers approaches in proportion, as has been proved in the foregoing proposition ; consequently the strength of a fortification increases in proportion to the number and length of its sides ; that is, a dodecagon is stronger than an octagon, supposing the length of their sides equal ; and an octagon, whose sides are 200 toises each, is stronger than another octagon, whose sides are only 180 ; and hence a right line fortified, is the strongest of all, contrary to the opinion of most engineers : there are even some, who imagine precisely the contrary to be true.

Mr. *Villeneuve*, a French author, at the end of his regular fortification says, that if, instead of fortifying a regular octagon in the usual manner, a square was made so as the sides are equal to 360 toises, or double the sides of the octagon ; and making flat bastions in the middle of these sides, so as three bastions being placed in a right line, the faces being 50 toises, and the perpendiculars 22 toises and 3 feet, which is one eighth of the exterior side ; this figure would be more advantageous than the octagon fortified in the usual manner.

As the angular bastions are weaker than the others by what has been proved before, he would have counterguards made before them, and their gorges retrenched, as likewise tenailles in the ditches: if this method be considered with attention, it will appear not altogether useless; for as the attack is reduced to the four angular bastions, they may be well secured by outworks, with less expence than the common octagon; for if instead of making tenailles, I would make rams-horns next to the flat bastions only in, order to increase the defence of the angular bastions, and if small lunettes were added next to the counterguards, so as to defend their ditches, it would encrease the defence considerably. This fortification has another advantage, which is, that the inside may be filled with regular buildings, and the streets made at right angles to each other, without losing an inch of ground. And though the capacity of an octagon is greater than that of this square, yet the latter will contain as many buildings as the former.

A late *English* author goes upon quite contrary principles; for instead of making an octagon, whose exterior sides are 180 toises each, he would make an enneagon, whose

whose exterior sides are to be 170 toises only; whereby he pretends to gain great advantages. But as an enemy is obliged to carry his works no farther than three sides, he will have less work to do in the attack of the enneagon than in the octagon; and as the angle of the polygon in the first exceeds by 5 degrees only that of the second, the small advantage arising therefrom, is by no means sufficient to ballance the disadvantage of lessening the sides; nor does it answer the expence of that bastion which is added to the octagon. Besides, we have proved, and it is allowed by the most able engineers, that the longer the exterior side of a fortification is, the stronger it will be, provided the lines of defence are not too long for musket-shot; because you can always place more men and guns in the works.

N. B. The truth of the foregoing proposition and its corollaries is likewise confirmed by practice and experience; first, as to practice, if the plan of *Namur* be considered, it will be found, that at *St. Nicolas* gate, where the town is narrowest, there are more works than in any other part; at *Cambray*, near the *Cantipers* and *Seille* gates, where the place is narrower than any where else, there

are horn-works ; at *Lille*, near the gate of the sick, is a castle in the curtain, a ravelin and counterguard before it, as likewise a horn-work before each bastion : abundance of other examples might be given, which confirm the foregoing proposition.

Experience has shewn likewise that large places moderately fortified, have made better defences in proportion, than small ones of more works ; for *Metz* in *Lorraine* was besieged, without success, by *Charles* the Vth emperor of *Germany* and king of *Spain*, although he had an army of 100,000 men, and the town was only fortified with a single rampart, without bastions and a dry ditch before it ; *Lille* in *Flanders*, when besieged by the allies, made a much better defence than any other place in that country ; and lastly, *Prague* in *Bohemia*, when besieged by the *Austrians*, which has but a rampart with bastions and a dry ditch, and yet the besiegers were obliged to abandon it, without being in a condition to take it.

An ingenious gentleman has observed very judiciously, that an army of 30000 men may easily defeat 40000 men divided into two or three parts separately, though not the whole together : the same reason holds

holds good in fortification; for one place fortified moderately, and garrisoned with 30000 men, will make a better defence than three equally fortified, with a garrison of 10000 men each.

It may be said, that these places had strong garrisons, skilful governors, and well provided with every thing necessary for a good defence, and that the *Austrians* before *Prague* were in want of artillery and ammunition to carry on the siege, and that the same place was taken a year before by the King of *Prussia* and the *French*, in the first assault. To this may be answered, that these places were only garrisoned in proportion to their extent, and *Lille* was obliged to surrender sooner than it would have done for want of powder and ammunition; and as to *Prague*, if the *Austrians* had been well provided with necessaries, they would have found it a difficult matter to force it, as may be judged by their beginning, since what works and batteries they made were destroyed by the besieged, and their cannon nailed up.

There are several other advantages in large fortified places, which cannot possibly be had in small ones; as that the sick and wounded may be lodged in a quarter remote

mote from the attack, where they are pretty secure from the besiegers shells and cannon-shot ; the several artificers necessary in a siege may do their business with less disturbance, and those troops which are not on duty may rest and refresh themselves, whereby they are better able to do their duty ; and lastly, the powder may be lodged in several magazines at some distance from each other, so that it is not in the besiegers power to destroy them, at least not all ; whereas it is a difficult matter to lodge powder in secure places in small fortifications, the sick and wounded are in a continual apprehension of being destroyed by the shells of the enemy, as happened in the siege of *Ostend* last war, where there was not any one place secure from danger ; and the troops not on duty, having no place to rest themselves in without fear, will never be able to act with that spirit as they would do otherwise.

It appears to me a vain imagination to think, that a fortification ever so strong, with a small garrison, can resist long a numerous army ; for if their loss is ever so inconsiderable in respect to that of the besiegers, it must nevertheless prove a great detriment to them in the end ; on the contrary, nothing

in my opinion, but a proportionable number of troops in a garrison, to that of the besieger's army, can make a proper defence according to the bigness of the place.

It may be said, that casemats or underground lodgements may be made for the troops to rest in and refresh themselves; but this cannot be done without great expence, and therefore the question is still, whether this expence is not better laid out in making a larger fortification, supposing the place is of sufficient importance to a nation; we except however those which are only made to defend a pass or a port, which might prove a temporary advantage to an enemy.

Having thus proved the foregoing proposition, and confirmed it by practice and experience, it will serve as a maxim or a general rule, on which irregular fortification is to be established; as likewise a standard, whereby the strength or weakness of those already fortified may be discovered.

As the situations of irregular places are so various, it is impossible either to enumerate them, or to give an example of each; therefore we shall endeavour to give such as are most common, and useful at the same time, by which the intelligent reader may be guided

guided in any other case that may occur to him.

If a situation is such, as to make it impossible to reduce it into a regular form, it should be brought to one as near as can be done; that is, if the polygon cannot be inscribed in a circle, it should be inscribed in an ellipsis or oval; but as this inscription is pretty difficult, we will give another method, which answers the same purpose, and is very easy in practice.

Pl.XXIV. Suppose a spot of ground to be reducible to the figure ACEG, draw BE, AF parallel to each other, so as the interval may be 180 or 200 toises, more or less, according as the nature of the ground will admit.

To these lines draw CH, DG perpendicular, and equally distant from the points B, E, so as their interval be equal to that of the lines BE, AF; this done, draw DC, GH parallel to AF, BE, and equally distant from them, and from their intersections C, D, H, G, with DG, CH, as centers, describe arcs, with a radius equal to CD, or GH, so as to intersect the lines AF, BE, in A, B, E, F, and join the points A, B, and E, F; then will ABCDEFGH be an oblong octagon, so that one half will be similar and equal to the other half.

Much

Much after the same manner may be described any other polygon ; for example, in an exagon, instead of drawing the two lines CH, DG, there need be but one, in a decagon three, and in a dodecagon four.

If it should so happen, as that all the sides cannot be made equal without too much expence ; then the sides AB, EF, on the narrowest part of the polygon, should be the longest, if possible, on account of its being the weakest, as has been proved before.

It may sometimes happen, that the figure cannot be made regular in any respect : in such a case, the strength of each side must be estimated according to the works a besieger is obliged to make in the attack, and according to the obstacles he meets with in his approaches.

If some parts of a place are commanded in front by a hill, the parapet must be raised 8 or 9 feet high, instead of six only, as is customary ; if it is in the reverse, then a traverse must be made along the capital of a sufficient height to cover the work ; or in both cases, cavaliers may be made nearly in the same form of the bastion.

It

It may sometimes happen, that there is an absolute necessity of fortifying a re-entering angle, in which case the works must be constructed in such a manner, that there may be no part but what can be flanked, or seen by some other part; in short, all that art and knowledge can furnish should be used in irregular works; the weakest parts should be made strong by an addition of works; care must be taken that no part be commanded by a neighbouring hill, or rising ground; and if that cannot be avoided, to raise traverses or cavaliers; in general, particular care should be taken to make every side equally strong, and to be as frugal in the expence as possible, that the expence of building and the maintaining a garrison, may not exceed the advantage arising from the fortifying of the place.

I have seen a project of a fortification which was to be built near a pass, to occupy a hill which commands a neighbouring fortification * of a very odd figure, although made by an engineer of great repute; it

* *St. Philip's castle in Minorca.* This hill commands the harbour as well as all the works of the castle, and yet it has been neglected hitherto; what use there can be made of it by the besiegers will I am afraid, soon be known, but hope this will caution us another time.

was impossible to judge, from the disposition of the works, for what intent the fortification was to be made.

When a place is to be fortified, it is of the greatest importance to employ skilful engineers to form the project; and to have it afterwards examined with great care and judgment by others, in order to be satisfied that the figure is properly adapted to the situation and nature of the ground, and the number of works answerable to the importance of the place; but above all things, the expence of building, as likewise the number of troops for the garrison, should be well considered; for without that it is morally impossible that the place should answer the end for which it is built.

Notwithstanding that the foregoing principles are or ought to be quite obvious to any one that has the least knowledge in fortification, yet many examples might be produced, wherein one would imagine that the projectors had not the least regard to this precept, but on the contrary they seem to despise all the principles which are not of their own invention.

Con-

*Construction of an irregular place
situated in an open country.*

If the place to be fortified is an old town inclosed by a wall or rampart, as it most frequently happens, the engineer is to consider well, all the different circumstances of the figure, situation, and nature of the ground, to regulate his plan accordingly, so as to avoid the disadvantages, and gain all the advantages possible ; he should examine whether by cutting off some parts of the old wall or rampart, and taking in some ground, the place cannot be reduced into a regular figure, or nearly so ; for, if that can be done without increasing the expence considerably, it should by no means be omitted ; old towns have often towers placed from distance to distance, as *Douay*, *Tournay*, and many other places, which are generally made use of, and mended when it may be done ; if there is a rampart without bastions or towers, it must be well considered, whether bastions may not be added, or if it is not better to make only some outworks ; if the ditch about this rampart is not too wide and deep, it would be advantageous to make detached bastions,

bastions, otherwise ravelins and counterscarps must be constructed ; special care must be taken, to make all the sides of the polygon as nearly equal as possible, and that the length of the lines of defence do not exceed the reach of musket-shot ; but if that cannot be done, those sides which are on the narrowest part should be made the longest.

If it should happen, that some of the sides are inaccessible, or of very difficult approach, either on account of some precipice, marshy ground or inundation, they may be made much longer than the others, which are of easy access, and the flanks need not be so large as the rest ; by doing so, there will be some expences saved, which may be used in making the other sides stronger, by adding more outworks.

There are few situations, but what are more advantageous in some parts than in others ; it is therefore the business of an engineer to distinguish them, and to render those sides strong by art, which are not so by nature.

If the situation is low and watery, lunettes or tenaillons, and such other small outworks, should be constructed, because they are not of any great expence, and may

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make

make a very good defence; but if one side of the place is only low, and running water is to be had, a second ditch and covert-way with lunettes, may be made, by observing, that if the first glacis is made to slope, so as to become even with the level of the water in the second ditch; or if the water can be swelled, by means of dykes or sluices, so as to overflow the best part of the first glacis, it should be done; for by so doing, these works will be able to make a very good defence, since the besiegers will find it a difficult matter to lodge themselves upon this glacis, which cannot be done but within a few toises of the first covert-way, where the besieged are ready to receive them, and to destroy their works with great advantage; whereas the enemy cannot support their workmen but from the second covert-way, which is too far off to be of any great service to them.

But if the situation is of a dry nature, without any water about it, caponiers should be made in the great ditch, from the curtains to the ravelin, and batteries raised in the entrance of the ditch before the ravelin, whose parapet must slope off into a glacis, so as to afford no cover for the enemy behind

behind them ; arrows and detached redoubts are likewise very proper to be used in such a case, and sometimes horn or crown-works, if it should be thought convenient ; but these works should never be constructed, without an absolute necessity, either to occupy a spot of ground which might be advantageous to the enemy, or to cover some gate or entrance into the town ; for they are of great expence, and their defence seems not to be answerable to it.

Most of the places in *Flanders* are fortified with horn-works, such as *Ipres*, *Tournay*, *Lille*, and others ; *Lille* has four, *Ipres* as many, two of which are injudiciously placed near one another. I am surprised that M. *Vauban*, who undoubtedly was in all respects the best engineer, and who fortified many places with so much judgment, should have been so fond of making these kind of works, which are, in my opinion, the worst of all his fortifications, in the manner they have been constructed in the above-mentioned places ; it must certainly have been before he had acquired that knowledge, for which he is so much esteemed ; and what renders this conjecture probable is, that he has but seldom made use of

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them,

them, in the construction of those places which he fortified in his latter time; and where he made any, it was always to cover a gate or entrance into the town.

If the place to be fortified is new, and the situation will not admit of a regular construction; particular care must be taken, in chusing such a spot of ground as is most advantageous, and least liable to any disadvantages, either in the building or in the maintaining of it; all hills or rising grounds should be avoided, which might command any part of the works, and marshy grounds, because such situations are unwholesome; or lakes and standing waters for the same reason, excepting a lake is, or may be made navigable; good water should be had either within the place or near it, for it is absolutely necessary for men and cattle; the air should be wholesome, otherwise the continual sickness that may reign in such a place might prevent people to come and live in it, and the garrison would not be in a condition to defend themselves as they ought to do; in short, all the different circumstances attending such an undertaking should be maturely considered, before a resolution is taken to fortify any place.

When

When a situation is pitched upon, the next thing to be considered, is the bigness of the town and the number of its outworks, which must absolutely depend upon the consequence such a place is of to a nation ; if it is only to guard a pass, or entrance into a country, it need not to be so large ; but if it is to be a place either to promote or to protect trade, it should be large and commodious : the streets should be wide, and the buildings regular and convenient ; as to what regards the fortification, its construction should depend on the nature of the situation, and the number of works, on the funds, or expence a prince or a nation will be at ; which however ought to be according to the benefit arising from such a place. For as such undertakings are of very great expence, an engineer cannot be too sparing in his works ; on the contrary, the greatest œconomy should be used, both in regard to the number of works, and to their construction. The body of the place may have * revetements quite up to the top, or only in part, and the rest turfed ; but as to the outworks, they should

* Revetements are chiefly made to prevent a place from being surpris'd ; outworks do not want to be made so, the taking them by surpris is of no great consequence, except in a siege, when other cautions are used to prevent it.

have half revetements, or they may be made with turf only; as being not so necessary to prevent the place from being surprised, and may nevertheless make a good defence.

The plate XXIV, is the plan of an octagon, one half of which is similar and equal to the other half; it being supposed that the situation would not admit of a fortification quite regular; the exterior sides are each 180 toises, and the works are constructed according to our method; but because the sides AB, EF are weaker than the rest, as has been proved before, we have added tenailles, redoubts in the ravelins, and lunettes, to render them nearly equal in strength with the others; and if counter-guards were made before the bastions A and B, it would effectually secure that front. Instead of lunettes, any other works may be made, as it may be thought convenient, and according to the nature of the ground. If it should be judged necessary to add other outworks to the ravelins all round the place, care must be taken to add likewise more to the fronts AB, EF, in order to render the advantages and disadvantages of attacking on either side equal.

Con-

Construction of an irregular place situated on a hill, or rock.

In the construction of such places, care must be taken that no neighbouring hill commands any part of the works, the town should always be built on the highest part ; but if it should be thought more convenient to place it lower, then the upper part must be fortified with a fort ; the situation should be made level as near as possible, by removing the earth from some places to fill up others ; and if that cannot well be levelled without extraordinary expence, works must be made on the highest part, so as to command and protect the lower ; the works ought to occupy all the upper part of the hill, but if it should be too extensive to be all inclosed, or so irregular as not to be fortified without great inconveniency, the parts which fall without should be fortified with some detached works, and a communication with the place must be made either above or underground. There should be no cavity or hollow roads within cannon-shot round about the place, where the enemy might be able to approach under cover ; if

there should happen to be a spring, near the top of the hill, it should be inclosed in the fortification, or if that cannot be done, by some work or other; for there is nothing more necessary, and at the same time scarcer in such situations, than water, for which reason there cannot be too much care taken in providing it; several cisterns are to be made to receive the rain-water, and to preserve it; wells should be dug likewise, though ever so deep, the water of which will serve for common use.

Places built on hills or rocks, should never be large, for their use is generally to guard passes or inlets into a country, and are seldom useful in traffick, and it is a difficult matter to provide for a large garrison in such situations; neither should any such place be built without some very material reasons; but when it is absolutely necessary, great care and precautions should be taken to render the works as perfect as the situation will admit of, and at the same time to be as frugal in the expence as possible.

Con-

Construction of irregular fortifications, situated near rivers, lakes, or the sea.

As the intent of building these kind of places, is chiefly to facilitate and protect trade, it is of much more importance than any other kind, especially in maritime countries, where the principal strength and power depends on it : for which reason, we shall treat of it more largely than of any other part.

The first thing to be considered is their situations, which ought to be such as to afford a good harbour for shipping, of a safe and easy entrance in stormy weather ; but as it is hardly possible to find any, where ships may go in and lie secure, with all winds, care should be taken to make them safe to enter with those winds which are most dangerous ; but it is not sufficient that the harbour is safe against stormy weather, they should likewise be so against an enemy, both by land and water ; for it often happens that ships are destroyed where it was imagined they were secure, which is of too great a consequence not to be provided against ; for which reason, forts or batteries must be built
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in the most convenient places, to prevent the enemy's ships from coming too near, so as to be able to cannonade those in the harbour, or sling shells amongst them ; and if there is any danger of an enemy's approach by land, high ramparts and edifices must be built, so as to cover them.

When a river is pretty large, and it is not convenient for making a harbour without great expence, the ships may ride along the shore, which, for that reason, must be made accessible for ships of burthen ; this may be done by advancing the quay into the river, if the water is too shallow, or by digging the river sufficiently deep for that purpose.

And to prevent any enemy from coming up the river, forts must be built on both sides, especially when there is any turnings or windings. *Antwerp* is such a place, for the *Scheld* is sufficiently deep to carry ships of great burthen, which may come quite near the town-wall ; and several forts are built below it on both sides, so that it would not be an easy matter for an enemy to come up the river.

When the river is but small, so that no ships of burthen can come through it ; it is sufficient to make it run through some
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of the works, where proper landing places are contrived, from whence the goods may be carried into the place; as at *Sarrelouis*, where a horn-work is built beyond the *Sarre*, in the gorge of which the goods are landed.

If the breadth of the river does not exceed 200 yards, it commonly passes through the middle of the town, and proper quays are made on each side; in such a case, the fortification is so contrived, as that the river passes through the curtain, in order to have a bastion on each side to defend the coming in and going out.

When M. *Vauban* fortified near rivers, he made always the exterior side near the water much longer than any of the others; such as *Hunningen* on the *Rhine*, and *Sarrelouis* on the *Sarre*; but for what reason he fortified these places in that manner, has not been told by any author I know of; for those who bestow most praises on him, are quite silent in this respect, although these works shew better, in my opinion, his great skill in fortification, than many others for which he is generally esteemed; it is true, authors treat in general so superficially of irregular fortification, as would incline one to

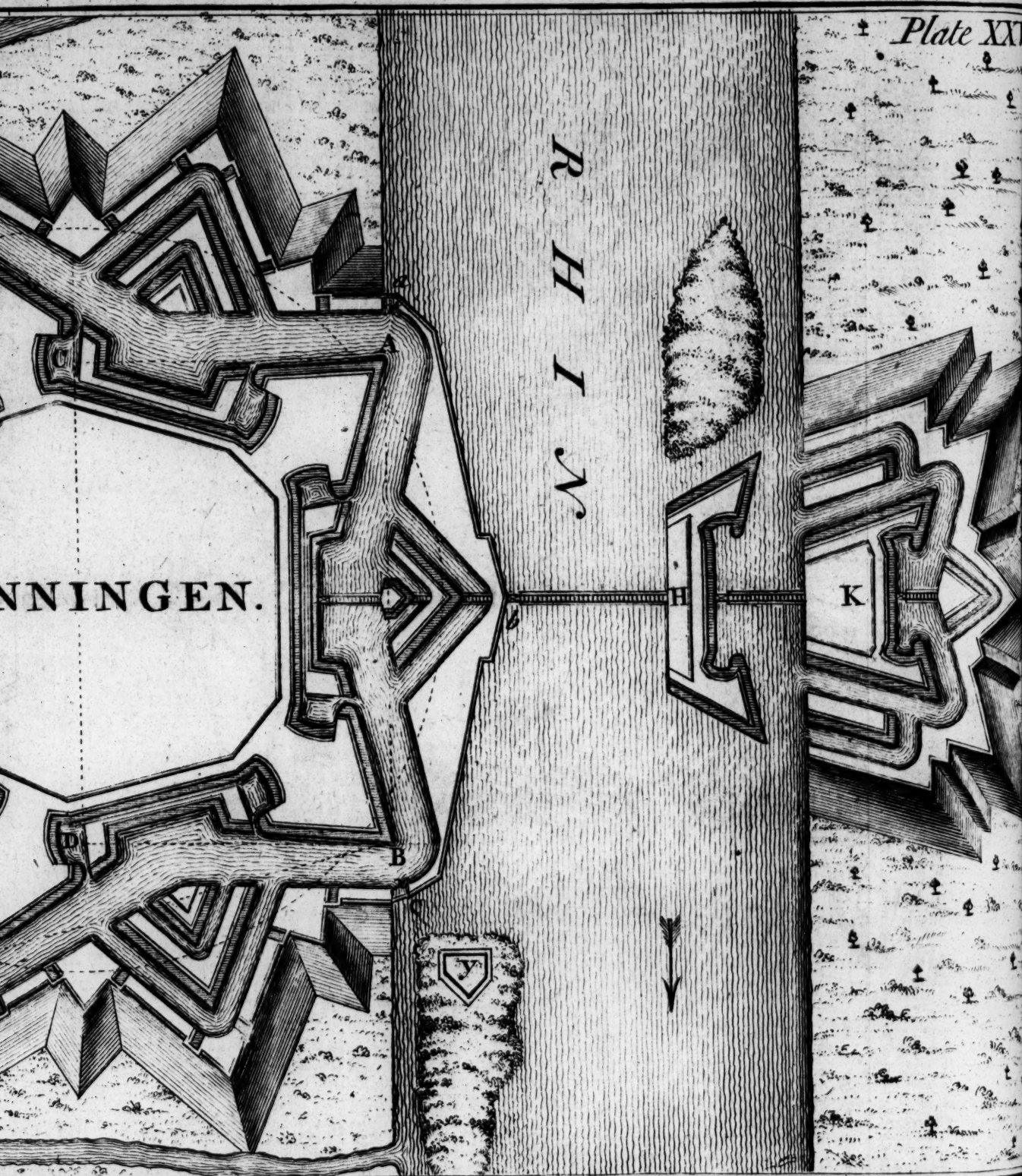
to believe that they either knew not the importance of the subject, or else imagined it was impossible to reduce it under general rules or maxims, whereby its perfections and imperfections might be discovered.

But it is plain, from what has been demonstrated before, that the sides which terminate at the river, are the weakest; because the besiegers trenches being secured by the river, they may draw most of their troops off, and act therefore with more vigour and strength on the other side: besides, as the strength of a side increases in proportion as the angle of the polygon is greater, by making the side next the river longer, the angles at its extremities become wider, and consequently the adjacent sides stronger.

There are other advantages, besides these mentioned already, which arise from the lengthening that side; for if the river is pretty deep, so as not to be fordable, that side is not liable to be attacked; and by increasing its length, the capacity of the place increases much more in proportion to the expence, than if more sides were made; the center of the place will be likewise nearer the river, which makes it more convenient
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for transporting the goods from the water-side to any part of the town.

To illustrate this method of M. *Vauban's*, we shall give the plan of *Hunningen*; this Pl. XXV. place was built for the sake of having a bridge over the *Rhine*, for which reason he made it only a pentagon; the side AB next to the river is 200 toises, and each of the others but 180; the body of the place, as likewise all the outworks, are constructed according to his first method, by observing that the perpendicular to the side AB is only 25 toises, according to the table given at the beginning of his first method, and the capital of the ravelin before that front 28; whereas those of the others are 50.

About the space *a b c*, which lies before the front AB; is a stone wall, and the passages *x, x* are shut up with sluices, to retain the water in the ditches in dry seasons, and to prevent an enemy from destroying the sluice near the point *c*, whereby the water would run out and leave the ditches dry; the redoubt *y* was built in the little island hard by, in order to cover that sluice; without this precaution the place might be insulted from the river side, where the water is shallow in dry seasons.

The

The horn-work K beyond the *Rhine* was built to cover the bridge, but as this work cannot be well defended cross the river, the horn-work H was made to support the other. There are likewise horn-works before the bastions E, F, and a little work before the bastion G, called *Paté*, which we have omitted for want of room.

There seems to be nothing in this fortification but what is well contrived, and here certainly the author has shewn his skill; the only things which appear to me superfluous, are the horn-works placed before the bastions, E, F, and the *paté* before the bastion G; for I think there are too many works considering the smallness of the place; and as the horn-works were chiefly made to secure a safe retreat over the wet ditch beyond the glacis, as I suppose, in case of a fall, a couple of detached redoubts might as well have answered the purpose.

Some of my readers will undoubtedly be surprised to read my encomium on this fortification, whilst M. *Coeborn* looked upon it as an ill-contrived piece of work; but if they will be pleased to consider that he was misled by a false or incorrect plan, for that very thing he said was wanting, meaning the
work

work *abc*, which retains the water in the ditches, was actually executed by M. *Vauban*, as this plan shews.

efore we finish the description of this plan, we shall shew how to find the long side *AB*, as being useful in the following work.

After having inscribed the two sides *GE*, *GF*, in a circle, draw the diameter *CD*, so as to be equally distant from the line joining the points *E*, *F*, that is, parallel to it; on this diameter set off 100 toises on each side of the center, from these points draw two indefinite perpendiculars to the diameter; then if from the points *E*, *F*, as centers, two arcs are described with a radius of 180 toises, their intersections *A* and *B*, with the said perpendiculars, will determine the long side *AB*, as likewise the other two *FB* and *EA*. In like manner may be found the long or short side of any polygon whatsoever.



When a place near a river is to be fortified, for the safety of commerce, particular care should be taken in leaving a good space between the houses and the water-side, to have a key or landing-place for goods brought by water; it should also be contrived to have proper places for ships and boats to lie
secure

secure in stormy weather, and in time of a siege ; and as water-carriage is very advantageous for transporting goods from one place to another, as likewise for bringing the necessary materials, not only for building the fortification, but also the place itself, the expences will be lessened considerably, when this convenience can be had ; for which reason places should never be built any where else but near rivers, lakes, or near the sea ; excepting in extraordinary cases, where it cannot be avoided.

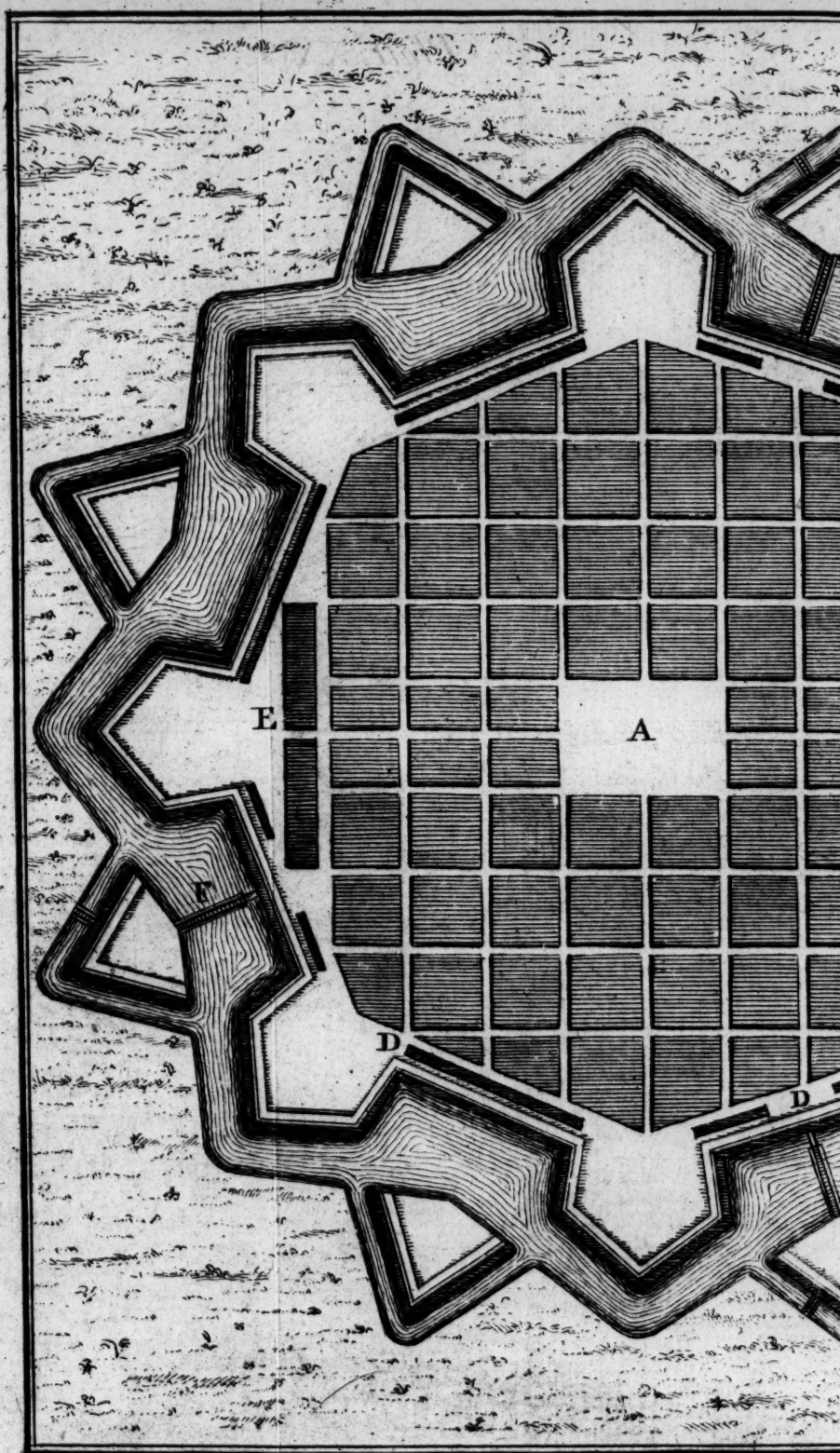
For the better understanding this important part of fortification, we shall give some examples of various kinds, from which the reader may gather the manner of fortifying others of the same nature.

EXAMPLE I.

PL. XXVI. We shall suppose a river of 100 toises or more broad, and such as is always navigable, at least for small vessels or boats, and the situation to be such as to admit of a regular fortification ; the body of the place is a regular octagon, and the flat side next to the river cuts off a fourth part from the circle, and is lengthened so as to be 360 toises ; the perpendiculars are 25 toises only on this side, and all the others 30 ; the faces 50, and the flanks

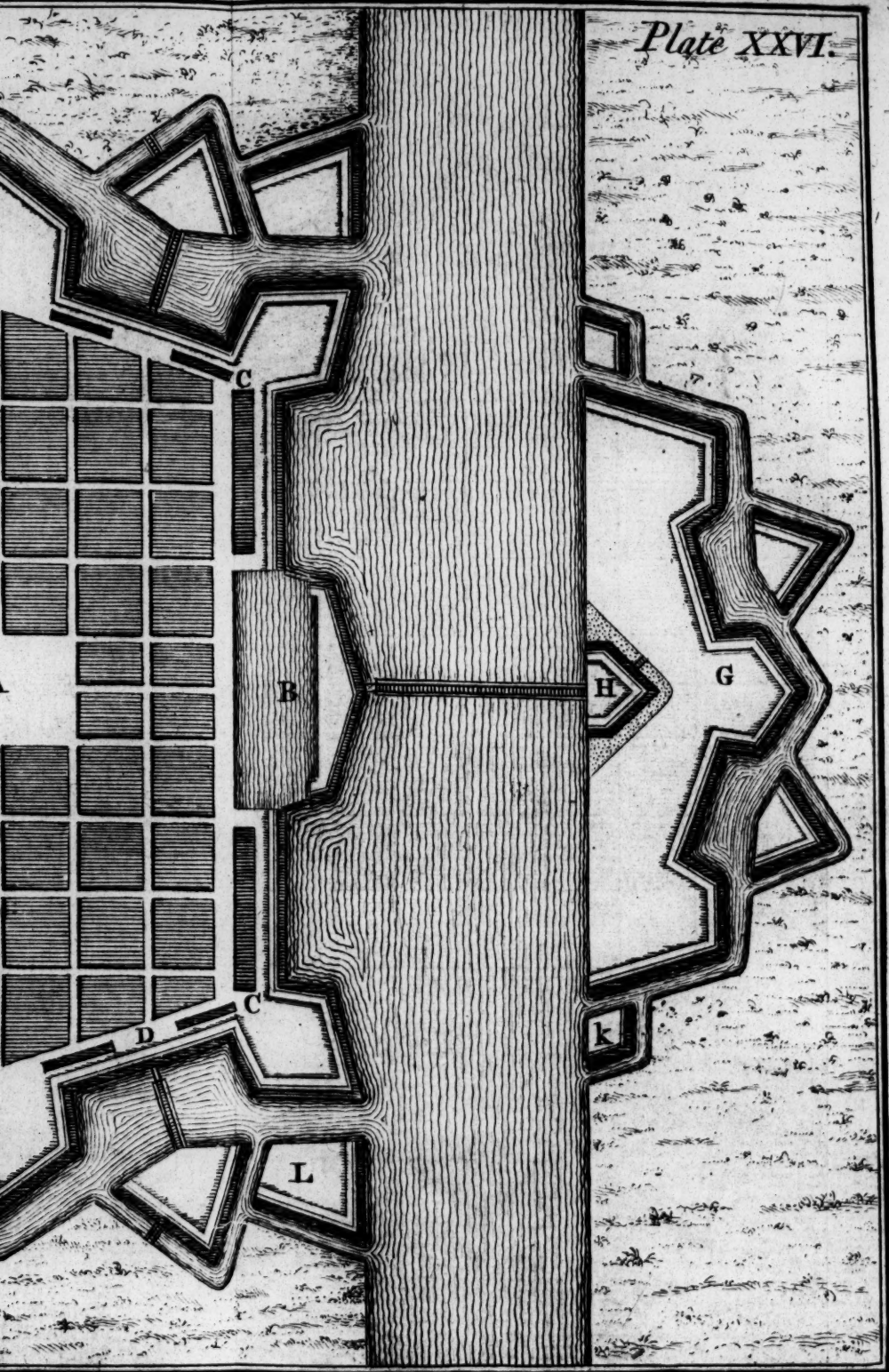
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Plate XXVI.



J. Myndesø.

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are found according to our method ; the great ditch is 16 toises, and the ravelins are constructed as usual ; the lunettes L near the river have one of their faces perpendicular to the middle of those of the adjacent ravelins, and the others are parallel to the flat side ; their ditch is 12 toises. Within the flat bastion is a bason B, to receive ships, 40 toises broad, and its length is terminated by perpendicular lines drawn from the extremities on the adjacent curtains, and a passage is made in each flank of 10 toises, for the ships going in and out ; these passages are shut up with sluices, with a kind of a passage over them, in order to have a free communication with the flat bastion, and from thence over the bridge into the fort G, on the other side of the river.

This fort is constructed in the following manner ; from the saliant angle of the flat bastion, as center, describe an arc with a radius of 200 toises ; on which set off two chords of 120 toises each, for the exterior sides, the perpendiculars to which are 20 and the faces 35 ; the branches of this fort are perpendicular to the opposite faces of the bastion ; the ditch before this work is 12, that of the ravelin 8 ; and the ravelin as well as the flanks are constructed according to our

N method.

method. The semi-gorges of the lunettes k are 20 toises each; and the faces are, the one perpendicular, and the other parallel to the branches of the fort; they serve to cover the entrance into the bafon B, which might otherwise be seen from thence; the ditch before these lunettes is 8 toises.

The gorge of the redoubt H is 40 toises, the flanks 10, the faces 30, and the ditch before it 6; this work serves for securing the retreat when the fort G is taken; and whilst the enemy is endeavouring to get masters of it, the troops may retire in the dark over the bridge into the town.

The market-place A is about 70 toises one way, and 50 the other; all the streets 6, which is rather too much for the bye ones; our design is not so much to give the particular dimensions of them, as to shew that they should be perpendicular to the river, and cross each other at right angles; reserving the rest for the practical part of fortification.

The buildings C, C, are designed for naval store-houses, E a store-house for land service, D for barracks, and F are the bridges near the gates of the town.

We have given the construction of the body of the place and ravelins only, without deter-

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determining the rest of the outworks, whose number and capacities depend on the importance of the place. It ought to be remembered, that it must be better fortified near the river than any where else, it being the weakest part, as has been proved before.

If the situation does not admit of a regular fortification, then it must be constructed in such a manner, as to approach as near to it as can well be done, without being at an excessive expence; and if there should be a hill, or rising-ground within cannon-shot, which can see into some of the works, it must either be fortified, or cavaliers are to be made in the opposite bastions.

It may sometimes happen, that the river forms a natural bason for shipping, or they may be made serviceable by a little work; such an advantage is by no means to be neglected, a skilful engineer will know how to use all the advantages which the nature of the ground affords, so as to be saving in the expences, and to make the place in the most convenient manner.

The landing places may be made in the great ditch, near the curtains next to the river, if it is thought proper; in such a case, part of those curtains may be left open, in order

to have a quay, and round these kind of harbours, some works should be constructed to secure the ships in time of war.

EXAMPLE II.

Plate
XXVII.

It may sometimes be judged more convenient to build the place on both sides the river, than on one only ; in such a case, the river should always pass through the curtains, in order to have a flank on each side, to defend its entrance and coming out ; if the river is not very large, the curtains may be built across the river upon arches, which may be made to shut in the night, or in time of a siege with portcullices ; and the middle arch may be made wider than the rest, and left open at top, with a draw-bridge over it, for ships to sail through. But if the river is above 100 toises large, the building curtains across would be too expensive ; in such a case a fort, such as B, may be made in the middle of it ; from whence chains and booms may be laid to the shore in the night, and in time of danger.

The construction of the body of the place may be as follows.

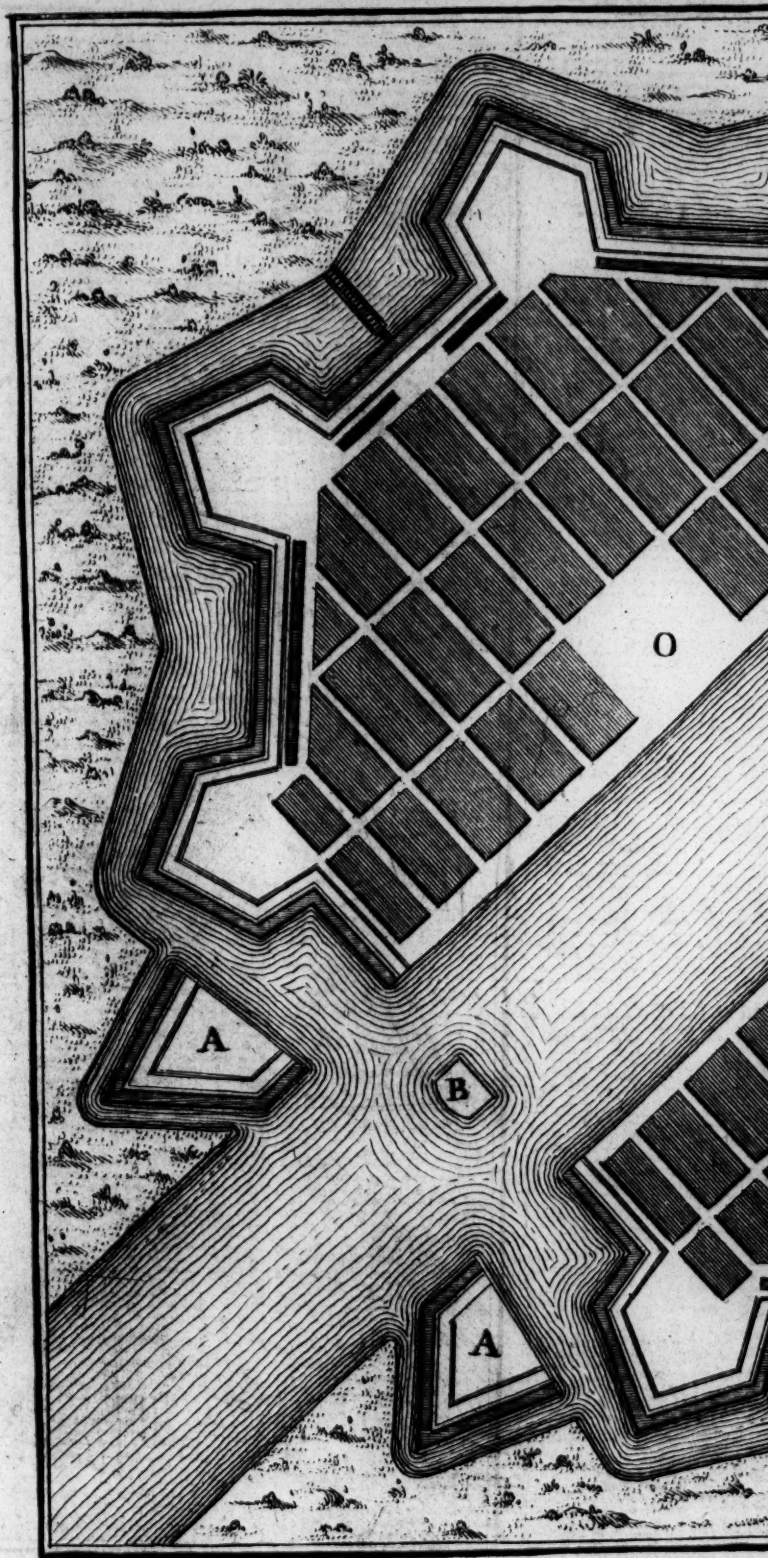
Supposing the situation to be such as to admit of a regular construction ; each side is

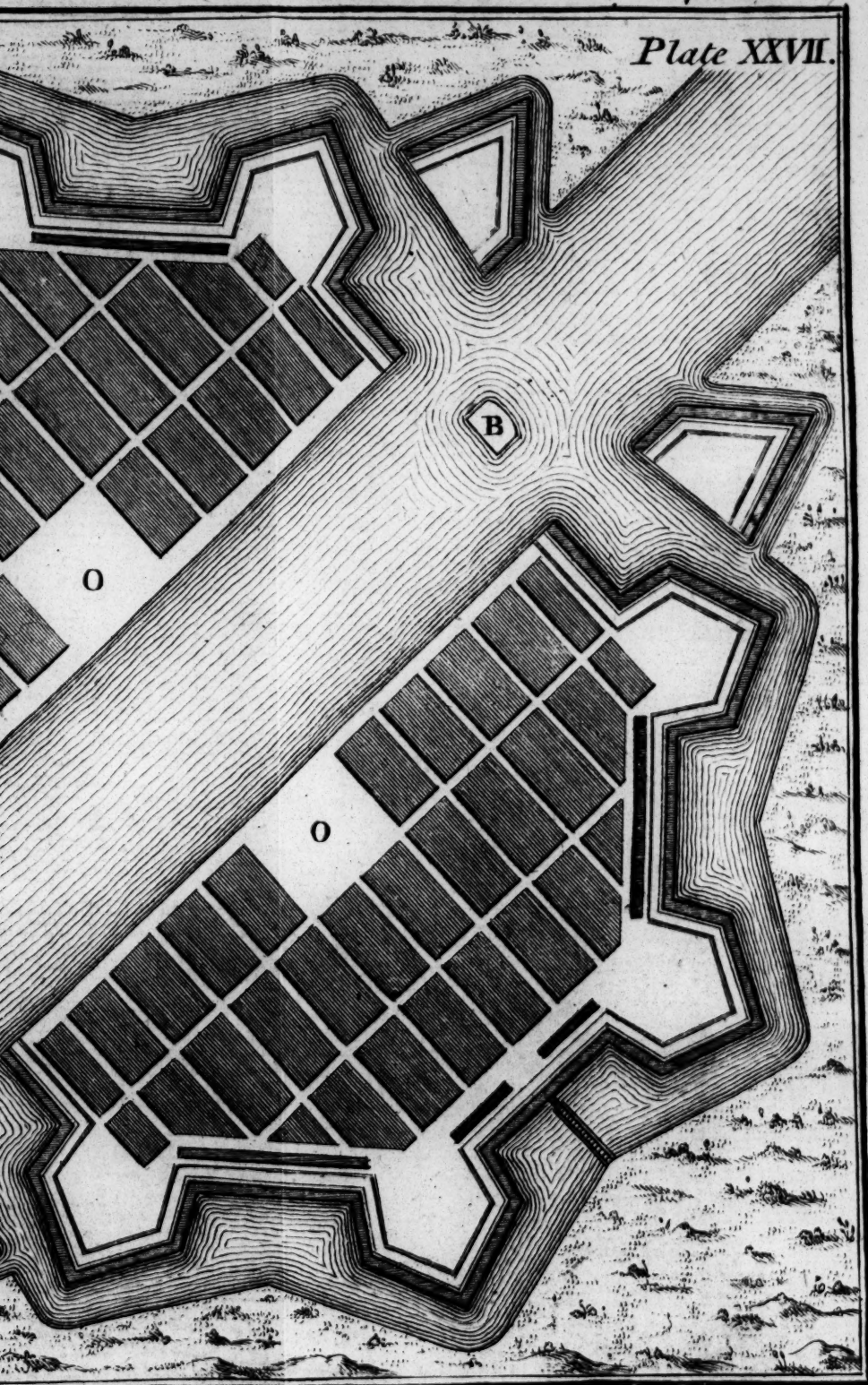
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a part of a regular octagon, inscribed in ^a circle, whose centers O are within 10 toises from the river ; the body of the place is constructed according to our method, and the ditch is 16 toises ; as to the rest of the works, their number and bigness may be made in what manner it is thought proper, and according to the importance of the place.

The streets are to be perpendicular to the river, and to cross each other at right angles ; and for a greater conveniency of transporting goods from the ships to the market, a market-place may be made on each side near the river. We have added lunettes, such as A, to defend the entrance and going out of the river, one of the faces of which is perpendicular to the opposite faces of the bastions within 25 toises of the shoulders ; this face is about 60 toises long, and the others are so drawn, as to be perpendicular to each other.

As the enemy will hardly attack the place near the river, because an attack made on one side only, is liable to be enfiladed from the other by the garrison ; and when it is made on both sides, the troops are divided, and not in a condition to support each other ; it is not therefore necessary to make the fortification stronger there ; on the contrary, as

it will probably be attacked on the side quite opposite to the river, some more works should be made in this place.

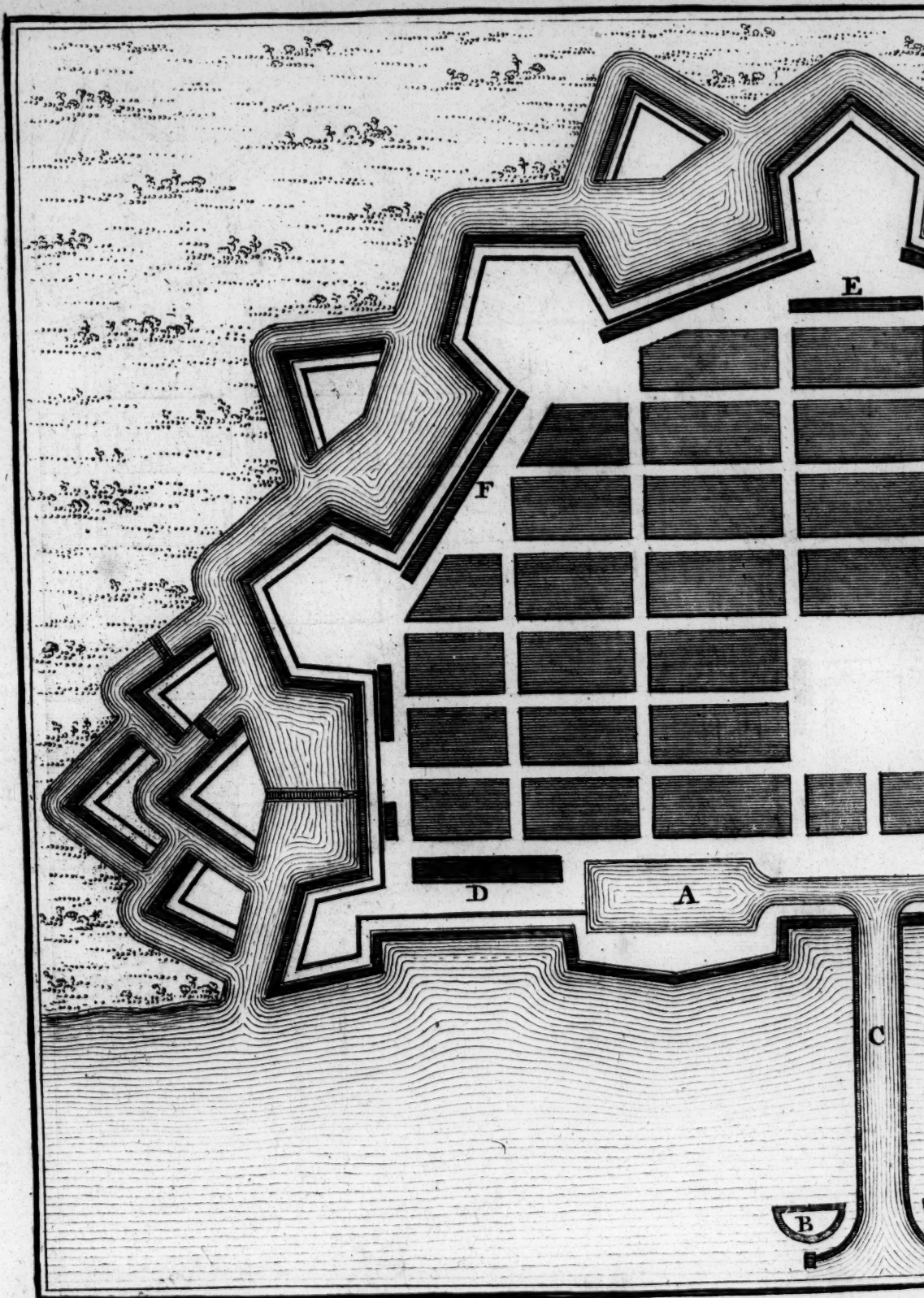
Notwithstanding the booms and chains, which are to be laid across the river, in the night and in time of danger, the enemy may find an opportunity to force his way through, whereby the place might easily be taken. To prevent which a wall of 8 or 10 feet high should be built along the river, with iron gates opposite to the streets, so as to be locked up at night.

EXAMPLE III.

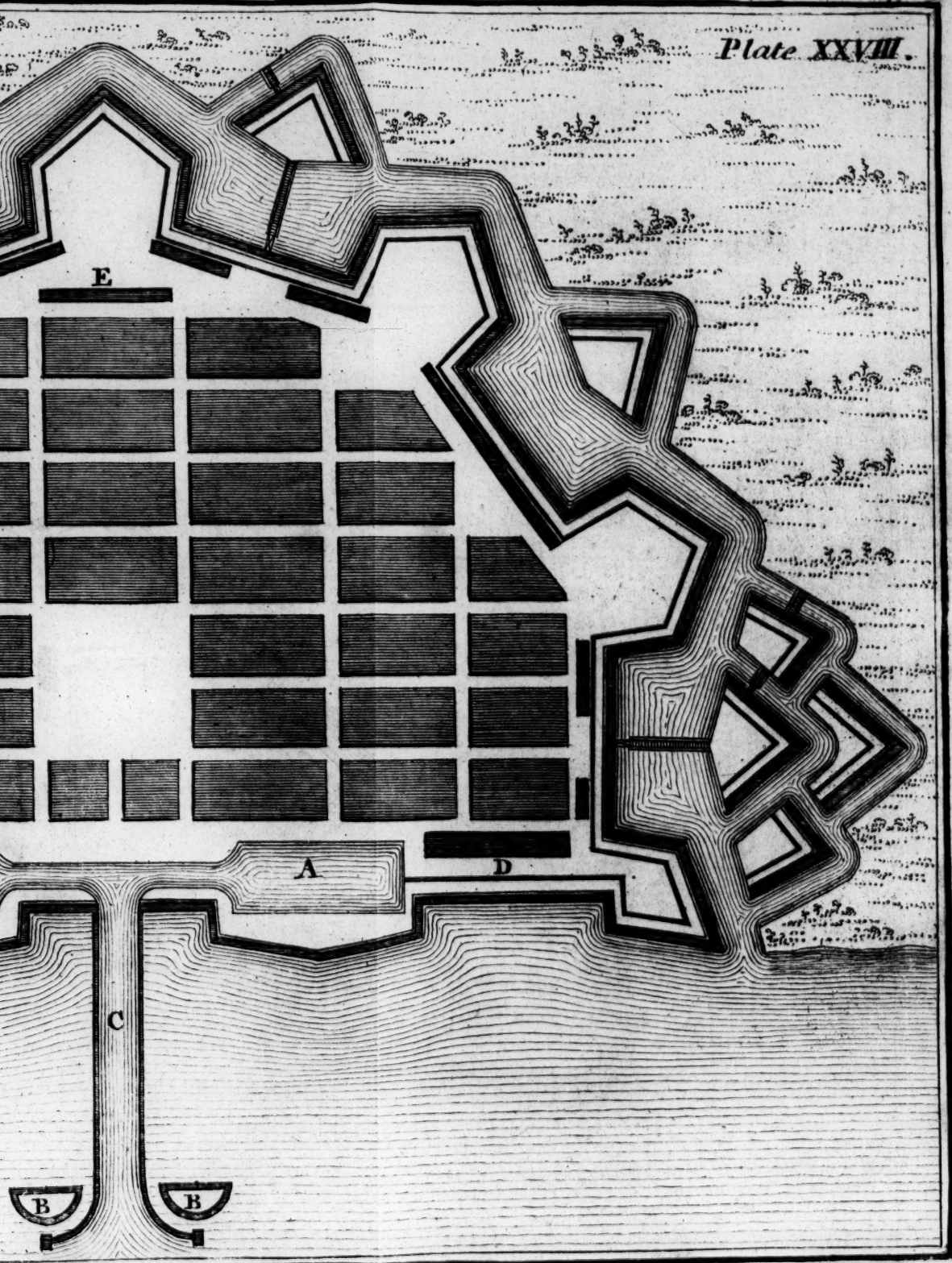
Places built near the sea are of the greatest importance to a nation on account of trade, so they require likewise the greatest care in the chusing their situations, in such a manner as to be of the least expence in building, and the most convenient for shipping. We shall shew how such a place may be fortified, when the situation is plain and even, and where there is no harbour formed by nature.

Plate
XXVIII.

This plan is a part of a regular decagon, four sides of which are cut off for the flat side next to the sea, the perpendiculars to which are but 15 toises; all the rest of the works are constructed as usual; as the place is weakest



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weakest near the shore, we have added lunettes with bonnets, to make it nearly equal in strength there with the rest of the sides; we have added no outworks besides ravelins and lunettes near the watersides, because their number and capacities depend on the importance of the place.

The basons or harbours A, A, are 30 toises broad and 80 long, and the entrance into them 10; this we imagine might be sufficient for ships going in and out: however, it may be made more or less, according as it will be thought convenient; our design being rather to shew the figure, and in what manner it may be done in some cases, than to pretend to give the exact dimensions, which ought to be determined by experience, or according to the nature of the situation.

The channel or road C, leading into the basons A, A, is 18 toises broad, and must be as long as the shallow water goes; B, B, are two semi-circular forts to defend the entrance into the harbour, which being made of that figure, are better for defence on every side. If these forts should not be thought sufficient, one or two more may be made between these and the place, or on some flats or sands where the ships cannot come too near.

THE ELEMENTS

The buildings D, C, are naval store-houses E a store-house for land service, and F the barracks.

The streets and other buildings are to be made nearly in the manner expressed here in the plan ; but the market-place might be made quite open to the sea, if it is thought proper.

We supposed here in this plan, that there is no harbour formed by nature, for which reason an artificial one is made ; but if there be any bay, creek, or large bason, formed by the sea, or a river, it ought to be used and enlarged, if necessary, and sometimes moles are made to form a harbour, as at *Gibraltar* ; by which a great deal of labour and expences are saved.

If a place is to be fortified in an island formed by the sea, and there is a navigable river, then the properest situation will be at its entrance, if the river is but small ; or a little way up in the land, if it is pretty large, so as not to be in danger of a bombardment from the sea ; but it must be observed, that here, and in all places of this kind, the conveniency for making a good harbour must chiefly be consulted, whose entrance should always be defended by two or more forts or batteries, placed on both sides of it.

It will also be proper to take particular notice, that if an enemy may land any where thereabouts, the forts must be built so as to be every where equally strong, in order to be in a condition to resist which way soever they may make their attack ; the want of this consideration has often proved of dangerous consequence, because if these forts or batteries may be surpris'd, the harbour will lie open to the enemy, who therefore may enter without any farther danger, destroy the ships, and take the town. It is by no means sufficient to raise batteries in such places as command the entrance of a harbour, without considering likewise whether their construction is such as to answer the purpose for which they are built, they will otherwise be of very little use in the defence of the place : if there should be but one or two such places where an enemy may land, they ought to be fortified with some small works ; but if there are several, it is much better to build two good forts, one on each side of the harbour, near some shallow water, so that the ships may not approach too near, to prevent their being demolished by them.

If a small island formed by a river is to be fortified, care must be taken to occupy
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the whole island if possible, in order that the works of the fortification may defend every part of the firm land, whereby the enemy will not be able to land any where without great danger and difficulty ; but if the island should be so large, that the whole cannot be conveniently fortified, and some parts are accessible and others not, the place should then be built in the most accessible part, and the others, if not too many, may be fortified with small forts or batteries.

If there is any lake of some length, or which discharges its waters into a navigable river, a place built near it will be very convenient for trade ; although a lake has no communication with the sea, or is not navigable, at least for large ships, yet it may be very useful for trading with the country round about ; the bigness and strength of such a place must be according to its importance.

We have thus explained, in a few words, the manner of fortifying places situated near navigable rivers, lakes, or the sea, which is far from being sufficient to give a complete notion of the subject ; it would require a whole volume to enumerate all the different circumstances that may possibly happen, either in respect to the various situations formed by

by nature, the conveniencies required to save expences, or their importance with regard to traffick ; for all these considerations are to be maturely considered and well weighed at leisure, before an undertaking of this importance is put in execution.

It would be a help to the reader, if a great many plans of places already executed were collected ; for by examining them with all the attention and care that is possible, and not omitting the least circumstances, arising from their different situations or nature of the ground ; as likewise from the importance they are of either to protect or increase trade and then taking notice for what reasons works are made in such a manner in one case, and different in another, a right notion might be formed of the subject, so as to be able to proceed in any other case of the like nature. But as this would swell the work too much, and draw it into a greater length than is agreeable to our purpose, we shall finish this part with explaining the situation of a few places already built, to supply, in some measure, what is wanting to complete the subject.

At *Dunkirk* is a bank of sand before the entrance into the harbour, nearly parallel to the shore, which is an admirable defence
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against any bombardment ; for when ships lie without it, they are too far from the place to do it any damage ; and if they should venture to go between this bank and the shore, there is a fort built so nigh, which would destroy them, as not having sufficient room for working a ship, so as to turn about ; the channel leading into the harbour is pretty long, and defended by two forts on one side, and three on the other, which makes it impracticable for an enemy to pass through it. Another great convenience this port has, is, that there are three rivers, coming from the inland country, which run into the harbour ; at their entrances are sluices, which are shut up at high water, and opened at low, which carry out the mud and sand brought in by the sea, and thereby prevent the harbour from being choaked up.

Whenever a situation is to be found, that has these advantages, it should not be neglected, since it saves great expences in keeping the harbour always clear, and renders an attack by sea impracticable.

Ostend lies close to the sea, and the road leading into the harbour, which lies opposite to the sea, passes by one side of it ; but as the entrance is very difficult, and no wind but a north-

north-west one will permit any ships to enter, and the town being liable to a bombardment, such a situation as this is not to be used, excepting other reasons occur for fortifying it; this place has one advantage, that it cannot be attacked by land but on one side only, which is along the shore, because all the other sides may be surrounded with water in the time of a siege, and therefore the accessible side may be made so strong, as to make it a difficult matter to take it that way.

This notion has been found to be erroneous in the last siege; for the *French* found means to place two batteries on the other side of the channel that leads into the harbour, the one fired into the entrance of the channel, and the other directly into the harbour. This last battery being seen, from the face of the opposite bastion, somewhat oblique, where 12 eighteen pounders were mounted, which would soon have silenced this battery, had the *French* not prevented it by tracing another epaulement parallel to, and about 20 yards behind the first, and making the embrasures of the last in a line with those in the first, by which they could fire into the harbour, and they were covered by the first epaulement against the guns of the place.

Antwerp

Antwerp lies near the *Scheld*, and has no other harbour than the river itself, which is large and navagable for ships of great burthen. A citadel is built above the town, to defend it against an enemy coming by land, and below are several forts on both sides the river, to prevent an enemy from approaching it by water ; this place is so happily situated, that it was formerly the principal trading place of all *Flanders* and adjacent countries ; but afterwards, when the *Dutch* had shaken off the yoke of the *Spaniards*, and the best part of *Flanders* was subjected to the house of *Austria*, the *Dutch* prohibited all the trade of this place, and transferred it to their own dominions.

By what has been said with respect to this place, the reader may easily perceive the great advantages it has ; and that few situations deserve so much notice to be taken of them as this.

Boulogne is situated near a creek going pretty far up the land, at the entrance of which is a bar difficult to pass without a good guide ; and on one side is a high hill which commands it entirely, so that the place is secure against any attack by sea ; for which reason, such a situation is not to be neglected.

Dieppe is another place situated near the sea ; the channel or entrance into harbour is guarded by two piers or moles, which harbour is nearly perpendicular to the sea, with a turning near the channel.

The channel and harbour of this place seem to be very convenient, and as they are chiefly formed by nature, the expence of making them must be inconsiderable ; but the places itself is situated so near the sea, as to make it liable to a bombardment, such a situation should therefore be avoided, excepting forts can be made so as to prevent the approach of an enemy's fleet.

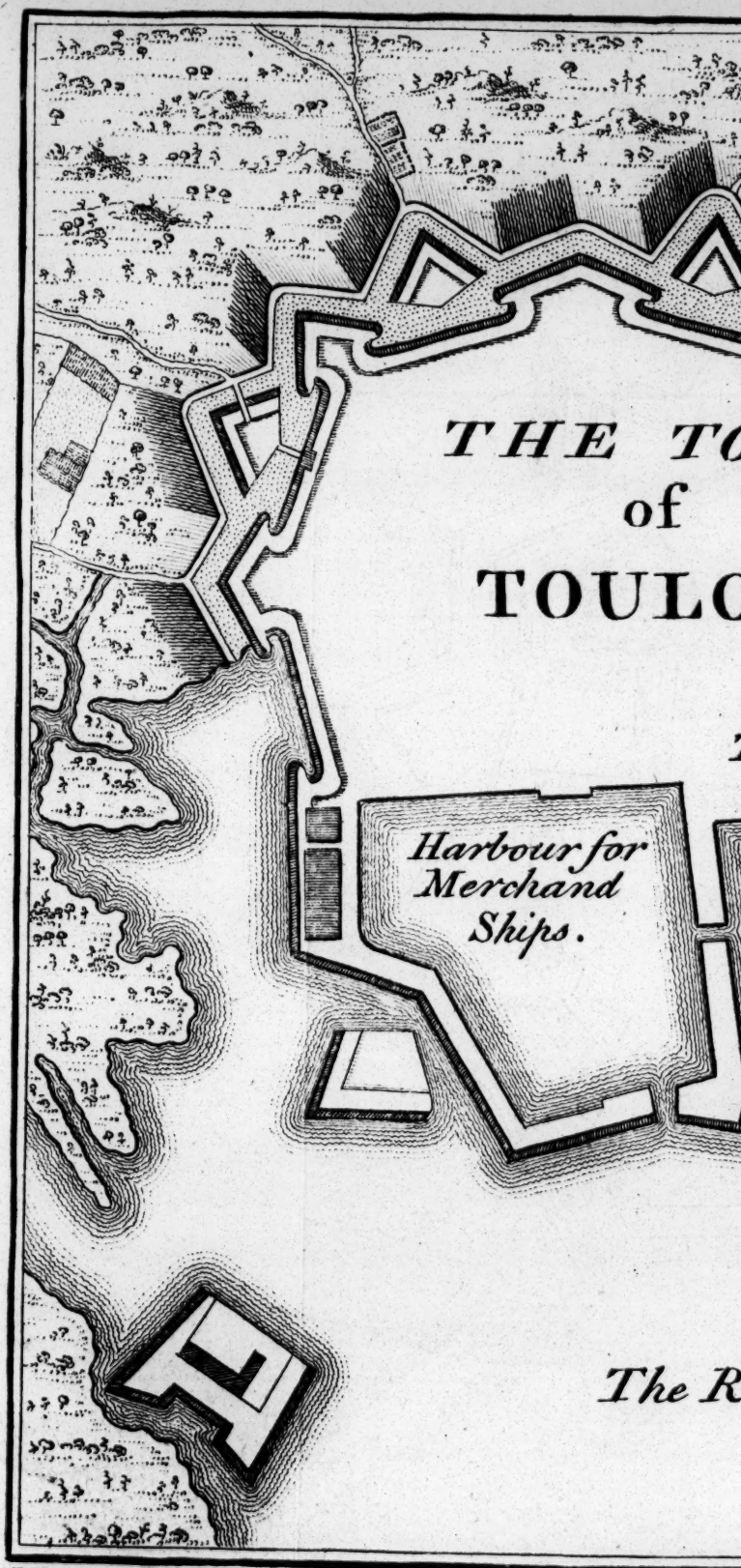
The last sea-port we shall mention is the famous one of *Toulon*, situated in the *Mediterranean* ; the entrance into the bay or road is large and spacious, covered by a neck of land, and defended by three castles, two forts and six batteries ; the road is so large, that a whole fleet may ride in it ; adjoining to the town are inclosed two large harbours by piers or moles, the one for the king's ships, and the other for merchant men ; the first is much larger than the second, and its entrance is made in the form of a V open at bottom, by which the ships are carried in gradually, without danger of running against the piers.

To

PL. XXIX. To give an idea of this*harbour, which is certainly one of the finest in *Europe*, we have represented the plan of the town and harbour only in the 29th plate, though it would have been much better for the reader's information, to have added the road and entrance likewise; but this could not be brought into so small a compass as to be inserted in this book, without rendering the parts indistinct. From this the reader may form a judgment how to proceed, if he should find himself employed in such sort of works: for nothing can be more instructive than examples of works executed; the precepts only, without them, will never make so strong an impression upon the mind as is required in the execution of any project, which must be perfectly well understood beforehand. Those who are curious in seeing the manner of forming harbours, may consult the second part of M. *Belidor's* Architect Hydrauliques, where they will find plans of the most noted harbours in *Europe*.

Before we finish this subject, we think it will not be improper to give the principal

* N. B. This plan has by mistake been reversed by the engraver; so that the king's harbour, which appears on the right, should be on the left.



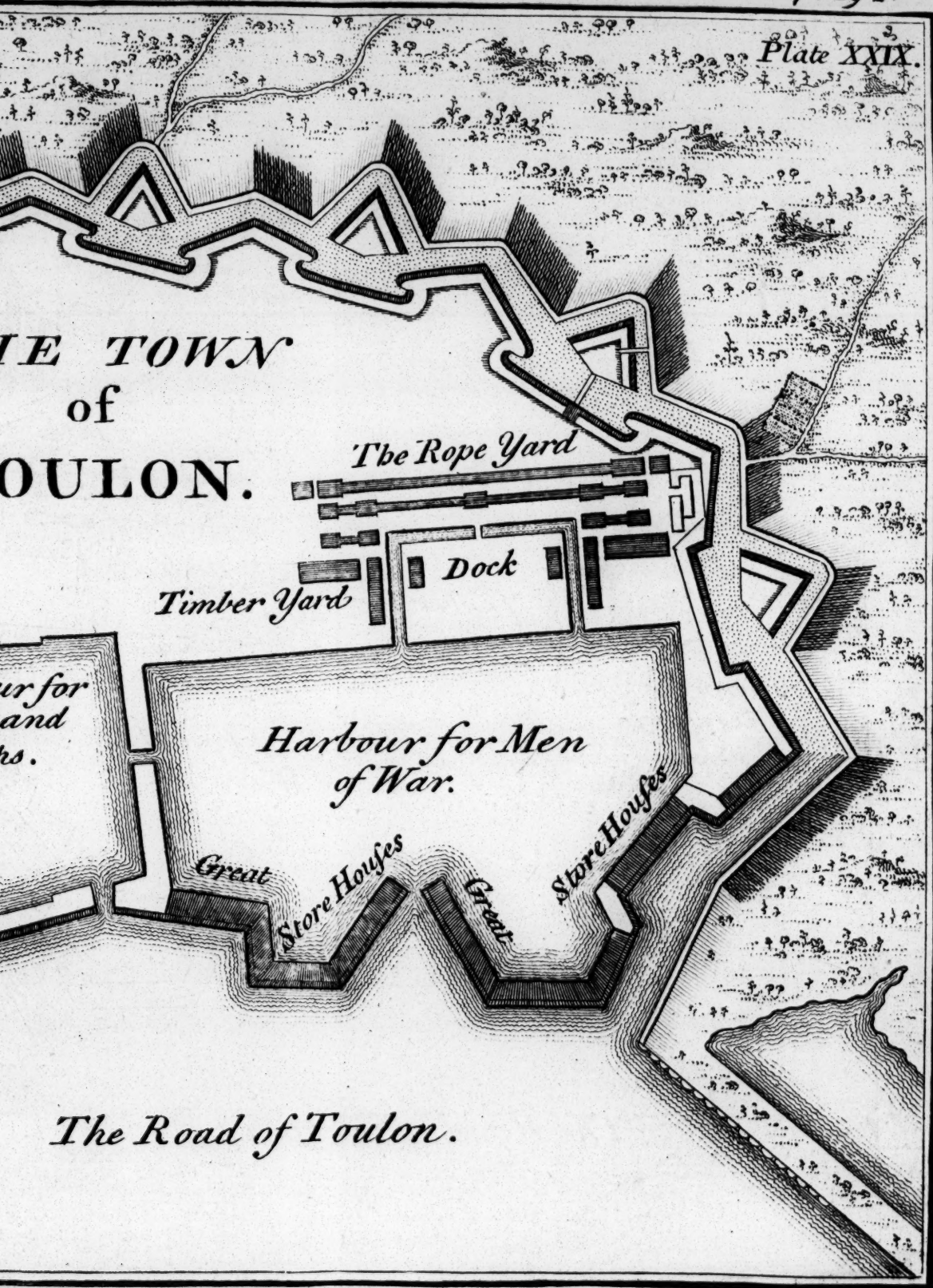
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conditions required in a sea-port town, and which ought to be observed in the building such places.

First, the harbour is of the greatest importance to all places of trade by sea; it ought therefore to be well considered, whether there is one to be found, which is formed by nature, such as a bay, creek, or a bason, or if by the help of a little labour one may be made; for to make one entirely by art, becomes generally too expensive, and they can never be made so large as to contain a considerable number of ships; whether the road before the harbour has a sufficient depth of water for ships of great burthen to ride in it safely; whether there is good anchoring, and the ships may be safe in stormy weather, and especially that ships may enter by such winds as are most dangerous upon that coast; if the entrance can be defended against a strong fleet, by means of forts, castles, or batteries built on each side of it; and lastly, whether the ships, riding into the road and harbour, are safe against a bombardment.

Secondly, whether the chief or principal materials for building the fortification and the town, are to be had near the place, or thereabouts; such as stone, timber, lime, &c.

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or if not, whether they can be brought by water, otherwise the construction of such a place would be attended with an immense expence; whether the country round about is plentiful in those things which are necessary for the sustenance of men and cattle; for should it be barren, the bringing these necessaries from distant countries might be attended with great difficulties, especially in time of war, when an enemy might intercept them, and thereby reduce the place by famine; whether the air is good and the situation wholesome in all respects, and good water to be found near or thereabouts; for if it should be unwholesome, people would not care to settle there, and those that would venture, would neither increase or act with that spirit and chearfulness required for the improvement of new settlements; and as to good water, it is so necessary, that it is impossible to do without it; lastly, it should be considered, whether the country round about it produces such commodities as are fit for trade; how it may be improved, and where it may be transported to, either for sale or exchange, for some others which may turn to account either at home or abroad.

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All these things being well considered, together with the nature of the ground, the plan of the place must be made accordingly; in which the construction of the works ought neither to be excessive in the expence for building of them, nor yet so small as not sufficiently to defend the place, but such as the importance of the place requires, and the situation admits of. As there are few situations which have all the advantages which could be desired, care must be taken to pitch upon such as have most of them, and where the rest may be supplied partly by art.

The most favourable situations for building maritime towns, are near the mouth or entrance of a navigable river, especially when it is free from rocks and sands, and is of easy access for shipping. In such situations, the harbour may be made on the opposite side of the place, in respect to the sea, as at *Ostend*, and some other places.

If the river is large, the place may be built at some distance from the sea, as *Antwerp*; and there is no occasion for a particular harbour, the river itself being sufficient; the only thing to be observed is, that there may be some place, where ships may be safe in stormy weather; a hill or rising ground near the ri-

ver, which shelters it from the most dangerous winds, will be very advantageous for that purpose.

These situations near large navigable rivers, not too far from the sea, are the most advantageous that can be found ; for they have all the advantages of a sea-port town, and are not liable to be attacked by an enemy's fleet, and are absolutely free from bombardment, excepting by land, since a few forts built in the turnings of a river will be sufficient to prevent any attempt that way : besides, the merchandise brought by water may be carried into the country to foreign markets with little trouble, and no great expence.

As the greatest wealth of a country depends on traffick by sea, so there is nothing of so great consequence, as the well protecting it, by building proper harbours to contain ships in safety, and to make them so, that they may be defended against the force or stratagem of an enemy : proper landing places should not be omitted, nor good magazines and convenient store-houses to lodge the goods in, and, in general, every thing should be thought of that any ways may contribute to easy conveyances, and the proper disposing of them. But as nature is so various in

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its operations, that it is impossible to foresee all the different circumstances which may happen, so it is likewise impossible to describe them, and consequently the choice of a proper situation, and the manner of constructing such a place, according to its importance, must be referred to the sagacity of the engineer employed in the undertaking, who certainly can have no larger field to display his knowledge, than on such occasions.

Of CITADELS.

In a country newly conquered, or one of a long standing, where the inhabitants are suspected of being disaffected to the government, citadels are built to keep them in awe, and prevent all attempts they may make to shake off their dependency; as likewise to secure the garrison from any treachery, which they might be willing to undertake against them.

It happens likewise sometimes, that when a town is large and wealthy, and has little or no fortification, a citadel is built to secure it against an enemy, when it would be too expensive to fortify the town itself; and to serve for a place of security, to carry in the best effects of the inhabitants in time of dan-

ger, when the approach of an enemy is apprehended.

There are many such places in *Italy*, which are large and wealthy, the sovereigns of which not being in a condition to fortify them, build citadels or castles, to save expences; as likewise to save large garrisons to guard and defend them.

In regard to the situation of a citadel, if the town lies in an open country, it ought to be built on the highest part of the ground, in order to command all the parts of the town, if possible; if the town lies near a navigable river or lake, it should be placed near the entrance, to prevent the approach of an enemy with ships; and if the place is a sea-port, the citadel should be placed near the harbour, so as to command it from one end to the other; that it may protect the ships lying in it, and secure the place against any bombardment.

Another consideration should be had in placing citadels, with respect to the town; which is, that the principal streets of the place should be seen and lie open to the works of the citadel, in order to fire on them and disperse the mob that might rise and flock together in time of a sedition; as likewise to prevent the approach of an enemy that way after the town is taken.

An open space, of some hundred yards broad, should be left between the works of the citadel and the town, called an *Esplanade* ; which serves chiefly to draw up the troops or garrison, to muster and exercise them there ; as likewise to prevent any hidden approach that might be carried on from the town against the citadel.

The figure of a citadel may be either a square, pentagon, or exagon ; but the pentagon is most proper, and generally used ; the exagon being rather too big for that purpose, as requiring too great an expence in the building, in proportion to its use, or the advantage arising from it ; and the square is thought too inconsiderate for making a sufficient defence.

When a citadel is to be built, either to an old place already fortified, or to a new one, its plan is to be traced by itself on a piece of paper, and upon the same scale as that of the town ; then the paper is cut off on that side which is to be next to the town, quite close to the edge of the works, and is laid on that of the town in such a manner, that the ditches and works of the fortification are well flanked and enfiladed by the works of the citadel ; and when it is placed according to its proper

situation, it is pricked off, and drawn upon the same paper as that of the place.

It happens sometimes that there is a hill, or rising ground, within the fortification of the place, on which the citadel is built; such situations may serve to keep the inhabitants in awe, if it is provided with necessaries, that the garrison may defend themselves, till such time that a relief may be sent; but they are of no manner of use against an enemy, who, after being in possession of the town, may easily reduce the garrison in the citadel by famine.

The exterior sides of the citadel are generally about 150 toises; but they may be more or less, as occasion requires. Particular care must be taken, to fortify the citadel stronger than the town, otherwise the enemy might attack it first, and by the help of which reduce the town; it must also be observed, to make the parts where the citadel joins the town sufficiently strong, otherwise the town and citadel might be attacked together. Most citadels that I have seen are defective in that respect, as we shall shew hereafter.

There are generally two gates made to a citadel, the one for a communication with the town, and the other with the country;
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the first serves for the garrison to retire into, in case of a sedition, or after the town has capitulated, and the other to receive succour, when the town is taken, or the citadel is blocked up by the inhabitants.

The citadel takes up generally two sides of the fortification, and ought to be placed in such a manner, that the ditch of the place may either be defended by the faces of the bastions, or by those of the ravelins, in as direct a manner as possible ; otherwise the enemy may attack the town in that place, as being weakest ; as likewise because the same attacks may serve to reduce both together. The covert-way of the citadel ought to be uninterrupted, so that the part next to the town may have a free communication with the other.

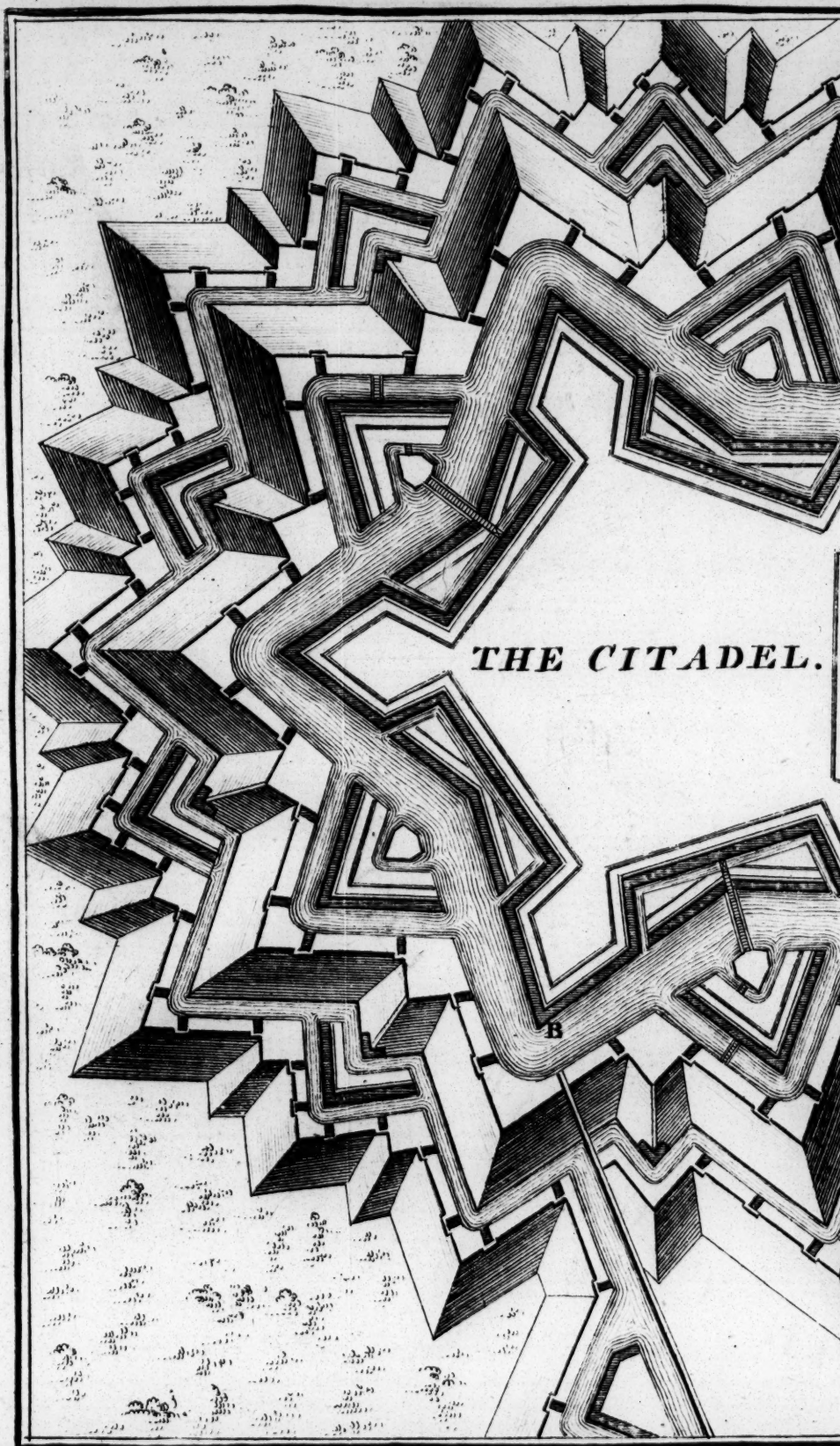
In general, a citadel should be constructed in such a manner, that an enemy may have no advantage wherever they made their attacks ; and that, if the citadel is attacked first, it may cost them as much time and trouble, as the attacking the town first, and the citadel afterwards.

There are few citadels, that, in my opinion, are rightly joined to towns ; the defence of the ditch is generally so oblique
and

and insignificant, that it appears strange they are not attacked there ; that of *Lille* is one
Pl. XXXI. of this kind. For the ravelin A cannot defend the opposite ditch in the least manner, nor is there any other work that can ; so that if the town was attacked in that place, the besiegers would meet with very little obstacle in the passage over this ditch ; neither does the bastion B defend the opposite ditch, which can be done only by the opposite covert-way, from which the troops may easily be driven by the ricochet batteries.

This plan is as the citadel has been built at first, but at present the second ditch and covert-way towards the town have been taken away, and new counterguards have been built before all the bastions ; and retrenchments have been made in the faces of these counterguards : which is a practice the *French* follow in all the counterguards and tenail-lons, whether constructed already, or when they make new ones.

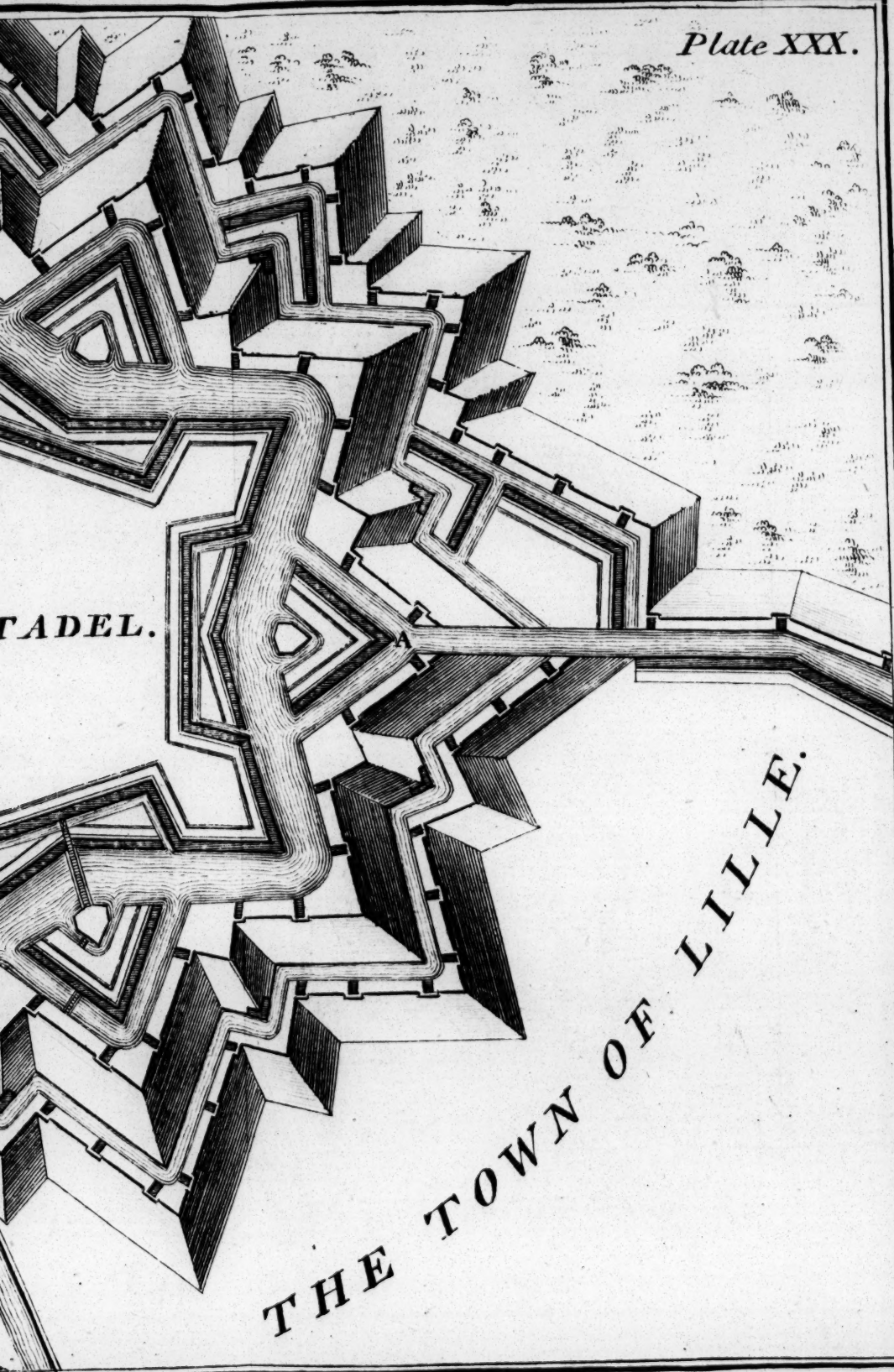
Pl. XXXI. The citadel of *Tournay* is another instance of this kind ; for neither the ravelin A, nor the bastion B, can afford any tolerable defence to the opposite ditches ; and as they are both dry, they are liable to serve an enemy for making their trenches in them under cover.



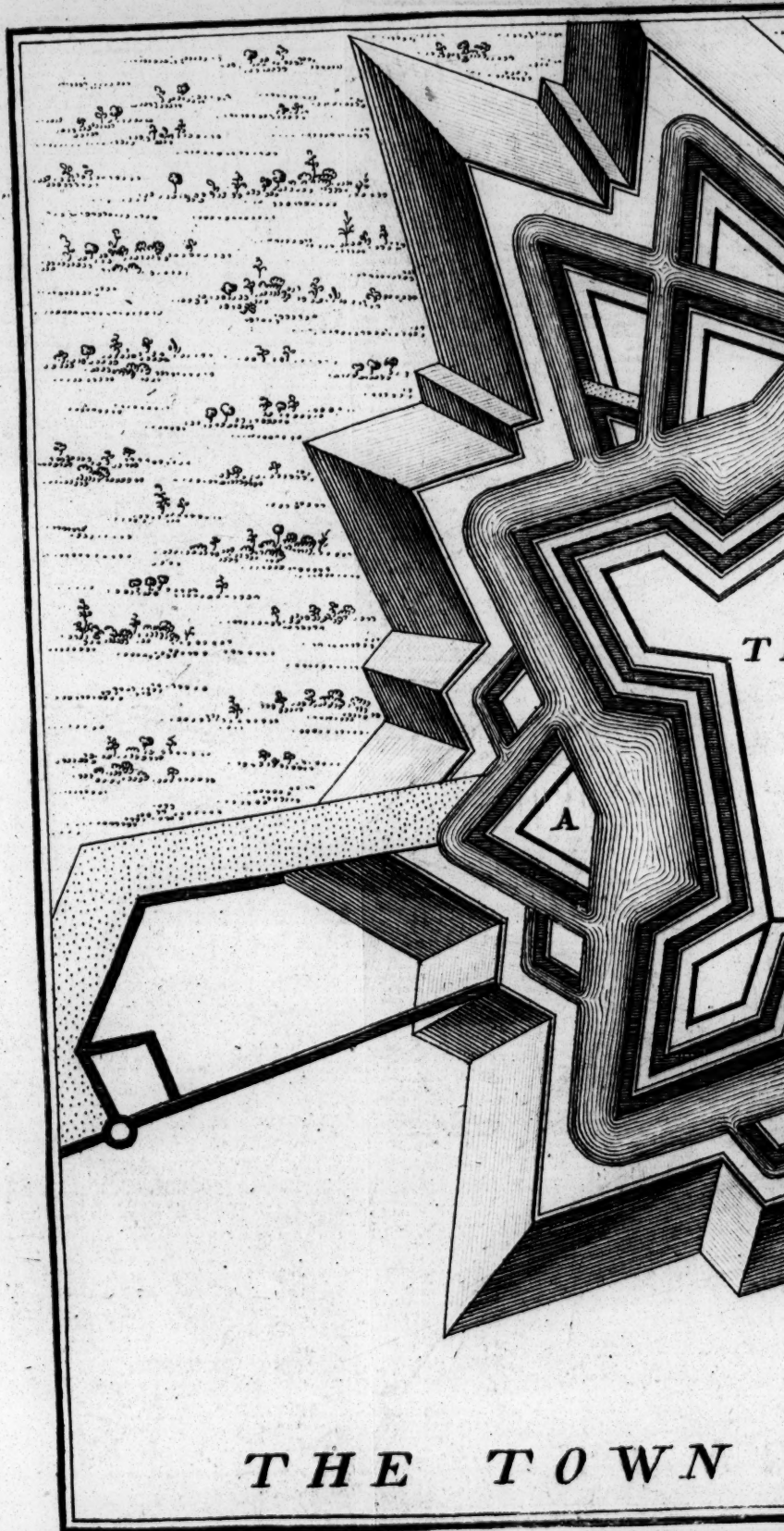
THE CITADEL.

Müller delin.

Plate XXX.



J. Mynde sculp.



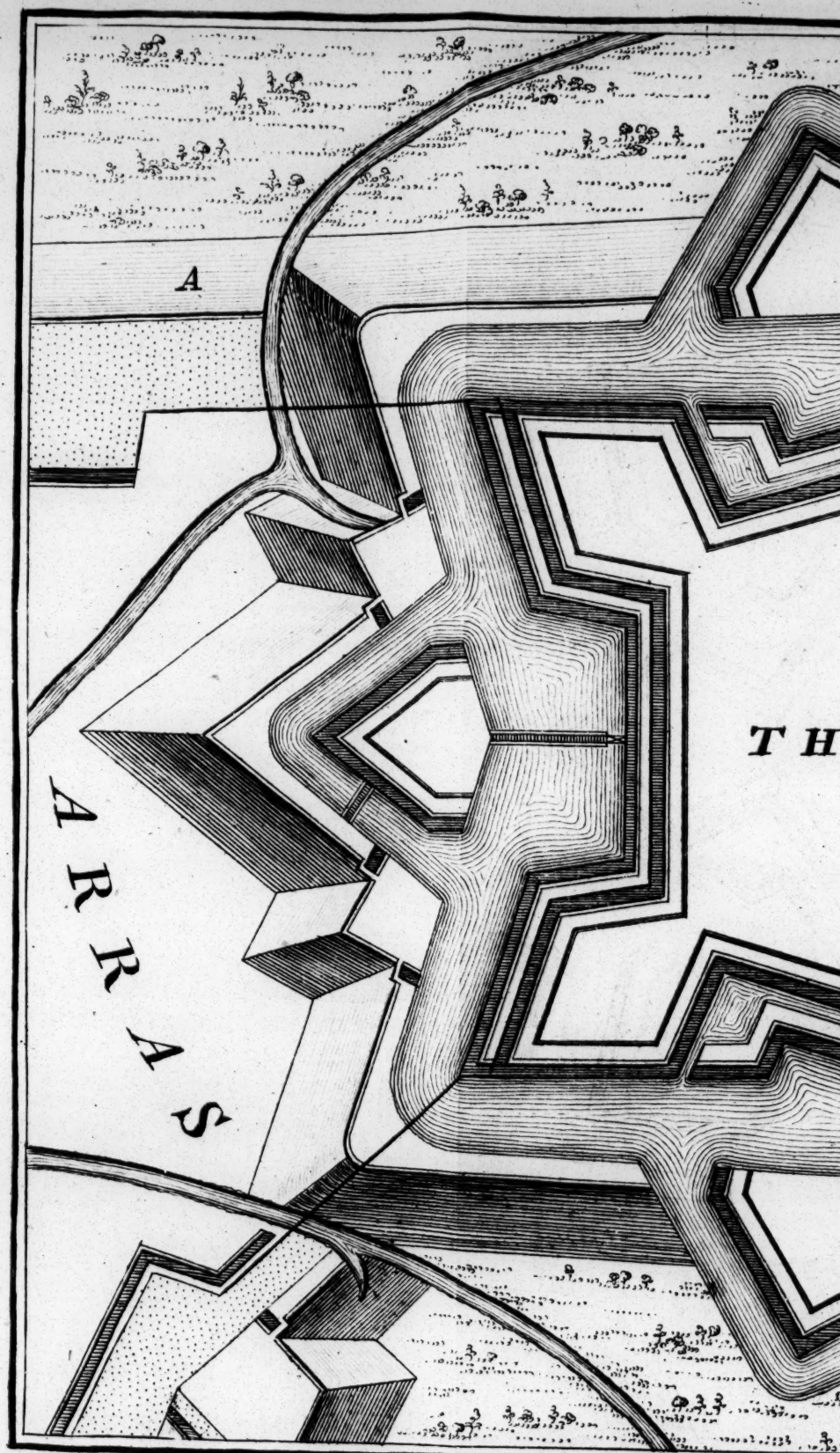
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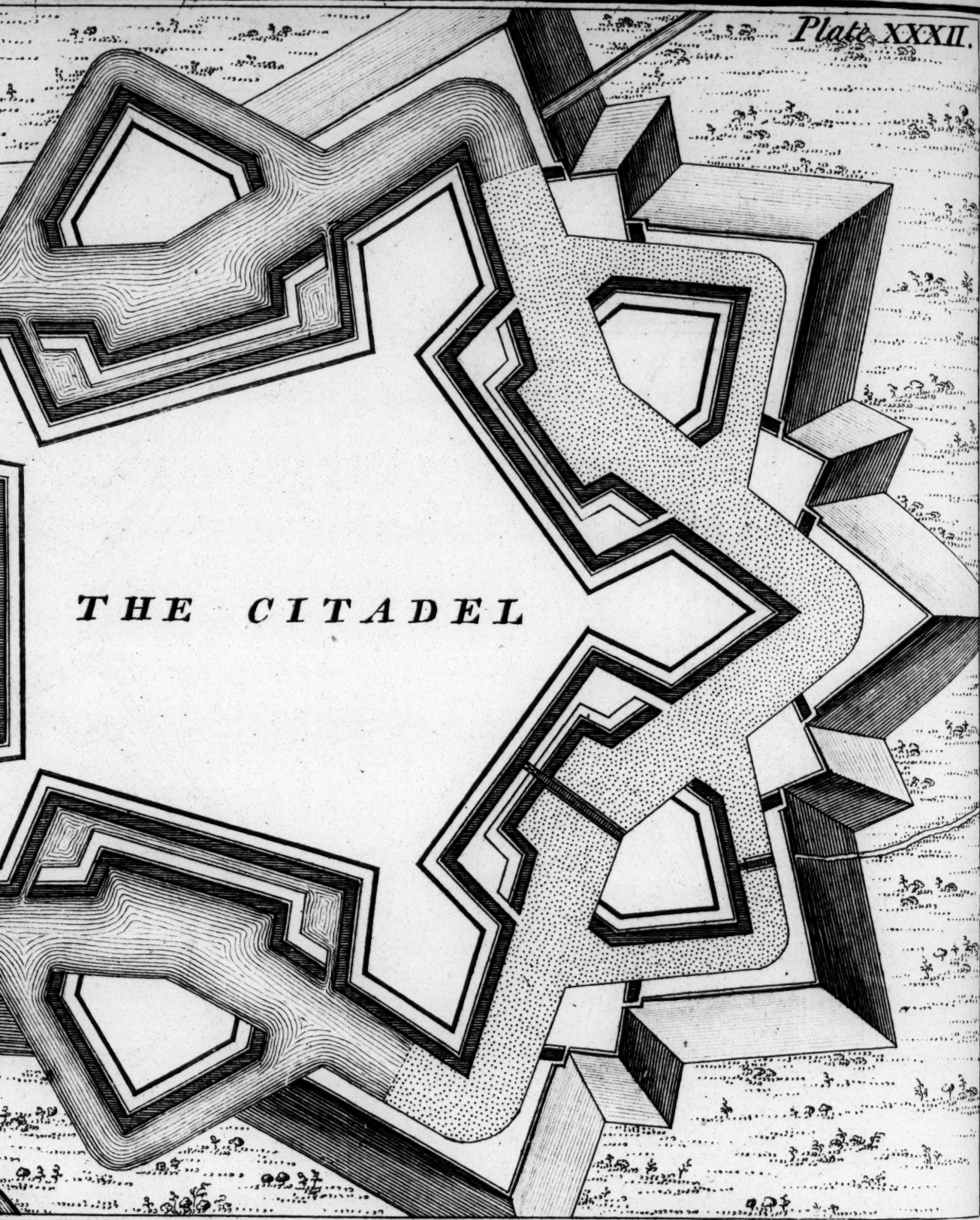
B

TOWN OF TOURNAI.

J. Mynde sculp



THE CITADEL



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cover. This General *Schullenbourg* was so sensible of, as not to let slip the opportunity, when he attacked that place in Queen *Anne's* war ; for he carried his approaches through that before the bastion B, and erected a mortar battery there; whereby the prodigious works above and underground of this citadel, which is esteemed to be one of the strongest in *Europe*, were of no manner of use.

It is a matter of surprise, that an engineer should take so much pains in fortifying a place, as M. *Maigrigny* did, and put a nation to so great expence, without considering rightly, whether it may make a defence accordingly, or having a due regard, in making every part equally strong, so as not to lose the advantage proposed by it, by neglecting some, whereby the whole expence is entirely lost, to the great disadvantage of a nation.

Lastly, the citadel of *Arras* is still in a ^{Plate} worse place than either of the foregoing ones; ^{XXXII.} for I do not see what should prevent an enemy from attacking the town near the citadel in the place A, since the troops being once driven out of that part of the covert-way, which is opposite to the ditch, by the ricochet batteries, which may soon be done, they might then as easily pass the ditch, as if there was no citadel ;

del; by which all the great works about the rest of the town would not be of the least use.

Before we finish this subject, it will perhaps not be improper to say something farther of citadels in general. When they are built with an intention to keep the inhabitants, who are disaffected to the government, in awe, methinks they need not be fortified so strongly as is customary; for if the garrison can only hold out till such time that succour may be sent, it would be sufficient: for which reason, if the town is fortified, by cutting off two bastions only, with some good retrenchment; it would answer the ends proposed as well, as the adding another fortification of so great expence, as is most commonly practised: and as these supernumerary fortifications add but very little strength to the place in proportion to the expence, it appears to me, that if a part of that expence were employed in adding more works to the town itself, it would be of more advantage.

The little defence made in the late war, by the citadels of *Lille* and *Tournay*, should, one would think, cure a prince of making these forts of works so expensive; but there seems to be a necessity of following the fashion in fortification as well as in dress, to avoid appearing ridiculous. It



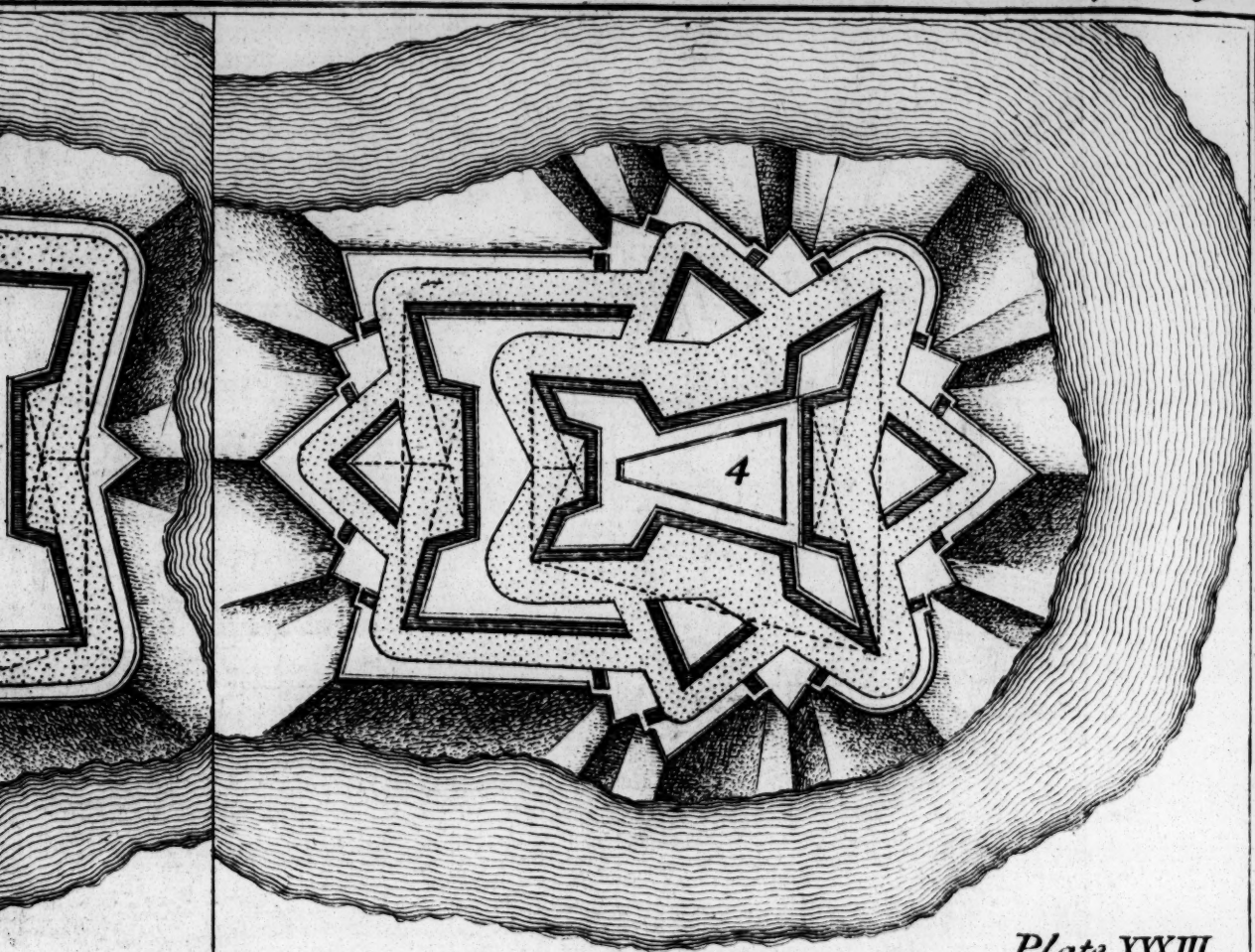
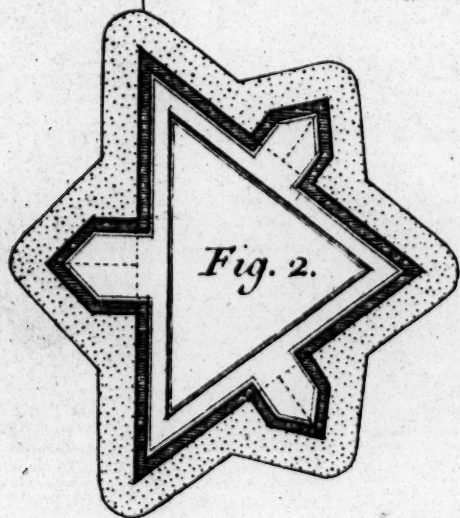


Plate XXXIII.



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It may be said, that the want of a good garrison, ammunition, and other necessaries, was the occasion of the short defences these two citadels made : it may probably be, that they were obliged to surrender somewhat sooner on this account. But if a large town is able to make as long a defence as there is any ammunition and troops to defend it ; there seems to be not the least occasion for any more works, which can but little increase the strength of the place.

Besides, it is manifest, by what has been said before, that a small place ever so well fortified, and provided accordingly, can never make the defence, which a larger may do with less works in proportion.

Of Forts and Redoubts.

Forts are a kind of small fortifications, ^{Plate} built in order to guard some passes, in a mountainous country, or near causeways, rivers, and other such like places. Their figure and bigness are various, and depend chiefly on the nature of the situation, and importance of the place : sometimes they are only made triangular, as in the first figure, with half ^{Fig. 1.} bastions ; but this sort is very imperfect, because the faces are not seen or defended from
any

any other part. If instead of being terminated at the angle, they were directed to a point within about 20 toises from it, they would be much better, as being then defended by that length of the rampart, though very obliquely. There should be a ditch of 8 or 10 toises about this fort, although we have not marked it in this figure.

Fig. 2.

Sometimes they are made as in the second figure, that is, triangular, as before, but instead of making half bastions at the angles, whole ones are placed in the middle of the sides. The gorges of these bastions may be from 20 to 24 toises, when the sides are from a 100 to 120; the flanks are perpendicular to the sides from 10 to 12 toises long, and the capitals from 20 to 24: if the sides happen to be more or less, the parts of the bastions are likewise made more or less in proportion; the ditch round this fort may be 10 or 12 toises wide.

The ramparts and parapets of these sorts of works are commonly made of turf, and the outside of the parapet fraised; that is, a row of pallisades are placed in about the middle of the slope, in an horizontal manner, the points declining rather a little downwards, that the grenades or fire-works thrown

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upon them, may roll down into the ditch : and if the ditch is dry, a row of palisades should likewise be placed in the middle of it, to prevent the enemy from passing over it unperceived, and to secure the fort from any surprise.

Forts are most commonly made square, as Fig. 3. in the third figure ; at least, when the pass they are to guard is of any consequence, or the place may easily be approached ; the sides of this square are 100 toises, the perpendicular 10, and the faces 25 ; the ditch about this fort may be from 10 to 12 toises ; the parapet is to be made of turf, and fraised, and the ditch palisaded when dry, There may be made a covert-way about this fort, or else a row of palisades might be placed on the outside of the ditch.

They are often made of various figures, regular or irregular, sometimes in the form of a semi-circle, especially when they are situated near a river, sea, or at the entrance of a harbour ; by which figure, they are able to fire at the ships on all sides of it ; at others with a long side, and several small ones without any bastions ; this should however not be done, but when they cannot be approached, without much time and difficulty : for it is
not

not supposed that any fort can hold out long against a superior force provided with artillery; their intent is only to prevent parties of an enemy to pass that way, and to stop them for some time till they may be succoured.

When a fort is to be built in the neck of land, formed by the confluence of two rivers, or in the windings of a river, in order to prevent an enemy from transporting any thing by water, or to prevent the passing of their ships that way; the figure of the fort must be adapted to the situation, in such a manner, that there may be no place for landing troops, but what can be discovered by the fire of some work or other, and the side next to the land should always be better fortified than the other parts near the river; as being more liable to be attacked.

Fig. 4. The fourth figure represents such a fort; three sides of which are a 100 toises each, and the fourth but 50, as supposing the ground to be narrow in that place; the perpendiculars to the greatest sides are 14, and the faces 30; the perpendicular to the other 10, and the faces 15: the capitals of the ravelins 25; the great ditch 12; that before the ravelin 8, and the covert-way 4 or 5. The narrow front towards the land is covered by

by a horn-work, whose front is at the distance of 36 toises from that of the fort, and 90 long, the perpendicular 12, faces 25, and the branches 10 toises broad at their extremities; the capital of the ravelin before this work is 22 toises, the ditch before the horn-work 8, and that before the ravelin 6 or 7.

We shall add another example of this kind, such as is represented by the fifth figure: Fig. 5. the land is supposed to open gradually; for which reason three sides are 100 toises each, and the fourth 160; the perpendiculars to the shortest 12, and the faces 30; that to the greatest 20, and the faces 45: the ditch before the three short sides is 12, and 18 before the greatest. The capital of the ravelin is 46 toises, its ditch 10; the faces of the lunettes are at right angles to those of the ravelin, and fall within 16 toises from the salient angle; these faces are 25 toises long, and the others are perpendicular to those of the bastions; the narrow part of the bonnet is 10 toises, and the faces are perpendicular to those of the lunettes, or parallel to those of the ravelin; the ditches before the lunettes and bonnet are 8 toises, and the covert-way 4.

P

There

There are generally great faults committed in the constructions of forts near the sea, or navigable rivers, for want of rightly considering all the different circumstances attending these sort of works, and without which it is impossible that a work will ever answer the intents and purposes for which it was built. For instance, if a battery or fort, built near the water where ships may approach, has its parapet not of a sufficient height; those behind them may be fired upon, from the round-top of the mast, by which the gunners are obliged to abandon their guns, to save themselves by flight; and so these forts or batteries become of little or no use.

This was the case at *Portobello*, when attacked by Admiral *Vernon*; for the forts and batteries, which were designed to defend the harbour, had been made so low, that the ships could come quite close to them, and the troops in them were soon obliged to take to their heels and run away.

There is generally another fault committed, which is, that if these forts or batteries are left open behind, or are very little fortified towards the land, the enemy may land men in the dark and surprise them, by which the
guns

guns placed in them become not only useless to the place, but serve rather to destroy it.

At *Carthagena* the *Spaniards* had a fascine battery on the other side of the entrance into the harbour, opposite to the camp, by which they prevented ships from going in; sailors were sent to take it, which was soon performed; but being satisfied with driving only the *Spaniards* from it, they were obliged to take it a second time to nail up the guns.

The same thing happened last war at *Cape Breton*, where the *French* had a battery of 15 large pieces of cannon; which the *English* surprised in the dark, and turned the cannon against the place, whereby they became soon masters of it. This fort was quite open behind, which being surprised by the sailors in the night, as we said, turned the cannon against the town and took it. Whereas if this battery had been secured in a proper manner, we might perhaps not have been able to take it, or at least it would have lengthened the siege considerably. Many examples might be cited of this kind, to shew, that the want of judgment in building these forts has proved a detriment, instead of an advantage, to the places which they should have defended.

To prevent the inconveniency of being seen behind the parapet, it will be necessary to make them 9 or 10 feet high, and to cover the batteries overhead, which may be done, by making an arch over every piece, left open behind to let out the smoke; but if this should be thought too expensive, they might be covered with planks, like sheds; and to prevent the wood being set a-fire, they may be covered with earth or dung about a foot and a half thick: for if it is but strong enough to resist musket-shot, it is sufficient.

And to prevent a fort or battery being surprised, they should be fortified all round with a good rampart and ditch at least, or with an addition of outworks, if the place is of any importance; the rampart must be fraised with palisades, if it is made with turf, and the ditch should have a row of palisades, planted in the middle of it, in case it is dry; which will prevent an enemy approaching unperceived.

It has been the custom, in latter times, for ships to approach forts and destroy them without any concern, as knowing too well the little danger they expose themselves to; and this has been occasioned by their bad construction; whereas, if they were made

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as they should be, it would not be impossible to sink every ship that should dare venture to come near them. The reason of this is plain, if we consider the uncertainty there is to fire from a ship, which is in a continual motion, and that a battery, covered with a good parapet, may watch the opportunity, when the ship comes near and opposite to it, and fire all the guns at once, pointing nearly at the same place a little above the water, which will hardly fail of destroying it.

On the contrary, if the guns of the ship hit the battery by chance, they can do it but little or no damage, when the parapet is well made.

There are some who are of opinion, that ships will always be able to destroy a fort, on account that they have more guns within a less compass than any battery on land can have; and if the contrary happens, it is more owing to the cowardice of the commander, than to any thing else, but this is a wrong notion, as we shall make appear. For suppose a first rate man of war, which has three decks, and therefore may have perhaps four, five, or six guns to one; the chance of hitting the battery, on account of the ship's motion, is not above three to one; and when the shot

strikes the parapet, it can do it but very little damage, excepting it should hit a gun by chance, which it would dismount; but this is not so easily done, considering the smallness of the gun with regard to their intervals; it is certain not one gun in 30 will hit; whereas the battery may watch the opportunity, so as when the ship comes near and opposite, to make a general discharge with all the guns, where there will be not one that misses, and every shot will make its hole into the ship, and destroy all things that are in its way. From whence it may be concluded with justice, that ships are never able to destroy any fort, when it is constructed in the manner it should be.

If the nature of the ground is so as to admit of making two batteries, one above the other, it should not be neglected; the one nearly a level with the surface of the water, to fire in a horizontal direction, and the other to plunge into the ships; so that if the troops are placed on the lower, being well protected in the front by a high parapet, and covered above with arches or planks, it will not be in the power of ships to destroy them, as has been done heretofore.

If

If there are any flats of sand, or rocks, near or within the entrance of a harbour, it will be very proper to build some tower or fort there of several stories, well arched, so as to be bomb-proof, in order to place several ranges of guns in them ; but as the smoke might be troublesome in the lower stories, I would make it open in the middle, that is, I would make two concentric walls, so that the arches of the roofs of the lower stories might be quite open behind ; and in case the enemy should throw shells, and hit the upper battery, it might be so contrived, that the shells may roll down the opening in the middle without doing any damage.

Fort *St. Louis*, in the road before the harbour of *Toulon*, is such a work, of a round form, built upon a rock, within the water ; and the towers called *Egilette* and *Vignette*, are places of the same nature in a square form, built upon the necks of land on both sides of the mouth of the road.

It is the custom of some modern engineers, when they build any fort or battery near the sea or navigable rivers, to make a parapet of three feet high only, in order to fire the guns en barbet ; the reason they give for this practice is, that they may point the guns which

way they please, either down the river, to prevent the ships from approaching, destroy them when they are opposite, or firing after them in case they should pass. However specious these reasons appear at first, yet when it is rightly considered, it will be found that this practice is not so advantageous as they imagine. For if they fire at the ships when they are yet far off, they can do them but very little damage; and the advantage gained thereby will not by far be equivalent to the danger they will themselves be exposed to, when the ships come near; since one broad side, together with the fire of the small arms, will be sufficient to kill or disable all those which are on the battery. On the contrary, if the batteries are well covered in the front by a good parapet, and above by planks, or only sail-cloth, and made in such a manner, as that some guns may be directed down the river, and others upwards; this battery will have all the advantage which they can pretend to gain by their practice, and none of its disadvantages.

Another method is also used in forts, much more defective than this, which is, to build the parapets of brick or stone only, without any earth behind it; for as soon as
the

the ships come once within reach of the fort or batteries, they may easily destroy this parapet, and the pieces of stones or bricks will be more dangerous to the defenders than the enemy's shot itself. And it has been found by experience, that nothing disheartens troops placed behind a wall so much as the pieces of stone flying about their ears, and therefore such a practice should be avoided as much as possible; besides, the adding 10 or 12 feet of earth only to the wall will be but a trifling expence, and yet sufficient to protect the troops from this danger.

Having explained the methods of the most celebrated authors, and carefully examined their constructions, to the best of our judgment, without the least partiality, we hope to have done all that is necessary to complete the elementary part of fortification; which being well understood, will, I hope, be sufficient for understanding the subject; and to leave nothing that might any ways contribute to the reader's satisfaction, we shall subjoin the following explanation of the principal terms used in fortification, by way of a dictionary, to which recourse may be had, when there is any occasion for it.

An

*An Explanation of the principal terms
used in Fortification, digested in an
alphabetical manner.*

A.

ANGLE of the center of a polygon, is formed by two radii drawn to the extremities of the same side.

Angle of the polygon, is made by the concurrence of two adjacent sides of a polygon.

Angle of the flank, is made by the curtain and the flank.

Angle of the shoulder, is made by the face and flank of the bastion.

Approaches, are a kind of roads or passages sunk in the ground by the besiegers, whereby they approach the place under cover of the fire from the garrison.

Arrow, is a work placed at the salient angles of the glacis, and consists of two parapets, each 40 toises long; this work has a communication with the covert-way of about 24 or 30 feet broad, called caponier, and a ditch before it of 5 or 6 toises.

Assault, is a sudden and violent attack, made uncovered, on the part of the rampart where a breach has been made.

Attack, is the manner and disposition made by an army or a great party, to drive an enemy out of a fortified place, or of any kind of strong situation.

B.

Barbet, when the parapet of a work is but three feet high, or the breast-work of a battery is only that height that the guns may fire over it without being obliged to make embrasures, it is said that the guns fire en barbet.

Bastion, is a part of the inner inclosure of a fortification, making an angle towards the field, and consists of two faces, two flanks, and an opening towards the center of the place called the gorge.

A bastion is said to be full, when the level ground within is even with the rampart, that is, when the inside is quite level, the parapet being only more elevated than the rest.

And a bastion is said to be empty, when the level ground within is much lower than the rampart, or that part next to the parapet, where the troops are placed to defend the bastion.

Banquette, is a kind of step made on the rampart of a work near the parapet, for the troops to stand upon in order to fire over the parapet ;

THE ELEMENTS

parapet ; it is generally three feet high, and as many broad, and $4\frac{1}{2}$ feet lower than the parapet.

Battery, is a work made to place guns or mortars on it ; consists of an epaulement or breast-work of about 8 feet high, and 18 or 20 thick ; when it is made for guns, openings or embrasures are made in it, for the guns to fire through them.

Berm, is a little space or path of 6 or 8 feet broad, between the ditch and the parapet, when it is only made of turf, to prevent the earth from rolling into the ditch, and serves likewise to pass and repass.

Blind, is two sticks fastened together by two spars of about 4 feet asunder ; they serve to cover the saps, or to keep up the earth on the sides, by placing fascines behind them.

Blockade, is the encompassing a fortified place with an army, so that it must either be starved or surrender.

Body of the place ; although the buildings in a fortified place are properly said to be the body of the place, yet the inclosure round them is generally understood by it : for it is said, to construct the body of the place, which means no more than to fortify or inclose the place with bastions and curtains.

Bombs,

Bombs, is the name of the ships which carry mortars.

Bombardment, is when a great number of shells are thrown into a place, to ruin and destroy the buildings.

Bonnet, is a sort of work placed before the salient angle of the ravelin to cover it.

Barracks, are those piles of buildings made on purpose to lodge the soldiers in them.

Breach, is an opening made in a wall or rampart, with cannon or mines, sufficiently wide for a body of troops to enter the works and drive the besieged out of it.

C:

Capital of a work, is an imaginary line which divides that work into two equal and familiar parts.

Capitulation, is the agreement made by the besieged with the besiegers, on what conditions the place is to surrender.

Camp, is the spot of ground occupied by an army for a night or more, and where they pitch their tents.

Caponier, is a passage made from one work to another, of 10 or 12 feet wide, covered on each side by a parapet, terminating in a slope or glacis.

Thus when the ditch is dry, the passage from the curtain to the ravelin, or that from the covert-way to the arrows or detached redoubts, are called caponiers.

There are often single parapets raised at the entrance of the ditch, before the ravelin, to place small cannons and men behind them to dispute the passage over that ditch, which are likewise called caponiers.

Cavalier, is a work raised generally within the body of the place, ten or twelve feet higher than the rest of the works. Their most common situation is within the bastion, and made much in the same form; sometimes they are also placed in their gorges, or on the middle of the curtain; they are then made in the form of a horse-shoe, only somewhat flatter.

The use of cavaliers is to command all the adjacent works and country about it; they are seldom or never made but when there is a hill or rising ground which overlooks some of the works.

Casemat, is a work made under the rampart, like a cellar or cave, with loop-holes, to place guns in it.

Chamade; when the governor of a place besieged wants to capitulate, then the drums

beat on the rampart next to the attack, which is called *chamade*.

Chevaux de Frize, are large joists or beams stuck full of wooden pins armed with iron, to stop breaches, or to secure the passages of a camp against the enemy's cavalry.

Covert-way, is a space five or six toises broad, going quite round the works of a fortification, and is adjoining to the counterscarp of the ditches, covered by a parapet $7\frac{1}{2}$ feet high, terminating in an easy slope towards the field, at a distance of 20 toises.

Center of the bastion, is the point within where the two adjacent curtains produced intersect each other.

Citadel, is a kind of fort or small fortification of four, five, or six sides, joined to towns, when the inhabitants are suspected to be disaffected to the government.

Command, when a hill or rising ground overlooks any work of a fortification, and is within the reach of cannot-shot; this hill is said to command that work.

Chamber, is that place of a mine where the powder is lodged.

Countermines, are the mines made within the fortification, either at the same time the place is fortified, or afterwards in the time of a siege.

Coun-

THE ELEMENTS

Counterfcarp, is the outside of a ditch, opposite to the parapet of the work behind the ditch ; it is often said, that the besiegers have carried their lodgements upon the counterfcarp, which means, they are lodged on the covert-way.

Counterguard, is a work placed before the bastions to cover the opposite flanks from being seen from the covert-way : they are likewise made before the ravelins.

When they are placed before the bastions, they are esteemed to be of a very good defence.

Crown-work, is a kind of work not unlike a crown ; it has two fronts and two branches ; the fronts are composed of two half bastions and one whole one ; they are made before the curtain or the bastion, and generally serve to inclose some buildings which cannot be brought within the body of the place, or to cover the town-gates, or else to occupy a spot of ground which might be advantageous to an enemy.

Cordon, is a round projection made of stone in a semi-circular form, whose diameter is about 8 inches, which reigns quite round the wall, within four feet from the upper part.

Curtain,

Curtain, is the part of the body of the place, which joins the flank of one bastion to that of the next.

Cuvette, or rather *Cunette*, is a small ditch of 10 or 12 feet broad, made in the middle of a large dry ditch, serving as a retrenchment to defend the ditch, or else to let water in it, when it can be had in the time of a siege.

Counterforts, or *Butteresses*, are solids of masonry, built behind walls, and joined to them, at 18 feet distance from center to center, in order to strengthen it, especially when it sustains a rampart or terras.

Communication, is a passage from one work to another, covered by a parapet on each side. See *Caponiers*.

D.

Decagon, is a polygon or fortification of ten sides.

Demi-lune, or *Ravelin*, is a work placed before the curtain to cover it, and prevent the flanks from being discovered sideways; it is made of two faces meeting in an outward angle.

Detached bastion, is that which is separated from the rest of the body of the place,

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and

and is made in the same manner as those which are joined to the body. Counter-guards with flanks are also called detached bastions, as in M. *Vauban's* second and third methods.

Detached redoubt, is a work made at some distance from the covert-way, much in the same manner as a ravelin with flanks.

Ditch, is a large deep trench made round each work, and the earth dug out of it serves to raise the rampart and parapet.

Dodecadon, is a figure or fortification of twelve sides.

E:

Escarp, is properly any thing high and steep, and is used in fortification to express the outside of the rampart of any work next to the ditch, as being high and steep.

Embrasures, are openings made in the flanks of a fortification, or in the breast-work of a battery, of about $2\frac{1}{2}$ feet within, 8 or 9 without, and 3 from the bottom, for the guns to enter partly, and to fire through.

Enfilade, a work is said to be enfiladed, when a gun may fire into it, so that the shot may go all along the inside of the parapet.

Epaulement, is a kind of breast-work to cover the troops in front, and sometimes in flank.

In a siege, the besiegers raise generally an epaulement of 9 or 10 feet high, near the entrance of the approaches, to cover the cavalry, which is placed there to support the guard of the trenches.

Esplanade, is an open space between the citadel and town, to prevent an enemy from making approaches under cover, after he is master of the place.

Enneagon, is a nine-sided figure or fortification.

Eptagon, a seven-sided one.

Exagon, a six-sided one.

Exterior side of a fortification, is the distance or imaginary line drawn from one point of the bastion to that of the next.

F.

Faces, of the bastion, are the two sides which meet in an angle projecting towards the field.

Faces, of any work, are those parts where the rampart is made, making an angle pointing outwards.

Q₂

Fascine,

Fascine, a kind of faggot made of branches tied in two or more places of about 6 or 8 inches diameter.

— They serve to keep up the earth in trenches, as likewise in batteries, instead of stone or brick walls.

When they are used in raising batteries, they are generally 16 feet long; and are then called *Saucissons*.

Fausse-bray, is a low rampart going quite round the body of the place; their height is about 3 feet at most above the level ground; and its parapet is about 4 or 5 toises distance from that of the body of the place.

These works have been intirely rejected by the modern engineers, excepting M. *Vauban*, who makes them only before the curtains, and then they are called *tenailles*.

Flank, in general, is a part of a work, which defends another work along the outside of its parapet.

Flank of the bastion, is the part between the face and curtain; the flank of one bastion serves to defend the ditch before the curtain, and face of the opposite bastion.

Flank (concave) is that which is made in an arc of a circle.

Flank (retired) is that which is made behind the line, which joins the extremity of the face and the curtain, towards the capital of the bastion. M. *Vauban* makes his 5 toises from that line, others more or less, as it happens.

Flanking, is the same thing in fortification as defending.

Flank (direct or grasing) is that which is perpendicular to the opposite face produced; and oblique or fishant, when it makes an acute angle with that face.

Flank (second) when the face of a bastion produced, does not meet the curtain at its extremity, but in some other point; then that part of the curtain between that point and the flank, is called second flank. The modern engineers have rejected this way of fortifying.

Fort, is a small fortification, made in a pass, near a river, or at some distance from a fortified town; to guard the pass, or to prevent the approach of ships, or an enemy by land.

Fortification, is a general name for any work made to oppose a small number of troops against a greater.

Fourneau, is the place of a mine, where the powder is lodged, and is the same thing as the chamber of a mine.

Fougass,

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Fougass, is a small mine, from 6 or 8 feet under ground; they are generally placed under the glacis or dry ditches.

— *Fraise*, a kind of stakes or palisades placed horizontally on the outward slope of a rampart made of turf, to prevent the work being taken by surprize.

When an army retrenches itself, they often fraise the parapets of their retrenchments in the parts most exposed to being attacked.

Fusée, is the piece of wood drove into grenades or shells, being hollow, and filled with mealed powder, by which the grenade or shell is fired.

G.

Gabion, is a cylindric basket open at both ends, of about 3 feet wide, and as much in height; they serve in sieges to carry on the approaches under cover, when they come pretty near the fortification.

Gabion, (stuffed) is made in the same manner as the former, they are only filled with all sorts of branches and small wood, and are 5 or 6 feet long; they serve to roll before the workmen in the trenches, to cover them in front against musket-shot.

Gallery,

Gallery, is the passage made under ground leading to the mines; they are from $4\frac{1}{2}$ to 5 feet high, and about 4 feet broad; the earth above is supported by wooden frames with boards over them.

Garrison, a body of troops composed of horse and foot, placed in a fortification to guard it in time of peace, and to defend it in time of war, in case an enemy should attack it.

Glacis, is that part of a fortification beyond the covert-way, to which it serves as a parapet, and terminates towards the field in an easy slope at about 20 toises distance.

Gorge, of a bastion, is the interval between the extremity of one flank to that of the other.

Gorge, of any work, is that part next to the body of the place, where there is no rampart or parapet; that is, at the counter-scarp of the ditch.

Grenade, is an iron ball of about 3 inches diameter hollow within; which is filled with powder, to be thrown by the grenadiers amongst the enemy in an attack, after having set fire to the fusée, that it may burst.

H.

Hornwork, is composed of a front and
Q 4
two

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two branches ; the front is made into two half bastions and a curtain : this work is of the nature of a crown-work, only smaller, and serves for the same purposes.

Half-moon ; see *Demi-lune*.

Hurtor, is a piece of timber about 6 inches square, placed before the wheels of a carriage, against the parapet of a battery, to prevent the wheels from doing damage to the parapets.

I

Insult, a work is said to be insulted, when it is attacked suddenly and openly.

Investing a place, is to surround it with troops, so as to prevent any thing to enter the place, or to be carried out of it : it is the first operation of a siege.

Interior side of a fortification, is the imaginary line drawn from the center of one bastion to that of the next, or rather the curtain produced to the centers of the bastions.

L.

Line of defence, is the distance between the salient angle of the bastion, and the opposite flank ; that is, it is the face produced to the flank.

Line

Line of circumvallation, is the work or retrenchment made about an army which besieges a place, to secure it against any insult from without ; it is made of a parapet which a ditch before it, and at every 120 toises, or thereabout, the parapet projects outwards in an angle ; this projection is called a *Redan*, and serves to flank or defend the other parts.

Line of countervallation, is the work made by an army which besieges a place between their camp and the town, to cover it against any enterprize of the garrison ; it is made much after the same manner as the line of circumvallation, only in a contrary disposition.

Line, is also the name of the works made by an army from one town or strong post to another, behind which it is encamped, to guard a part of the country.

Line of counter-approach, is a kind of trench made by the garrison when besieged, going from the covert-way in a right line, so as part of the enemy's approaches may be enfiladed from thence.

Lodgment, is the work made by the besiegers in some parts of fortification, after the besiegers have been drove out, to maintain it.

Loop-

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Loop-holes, are square or oblong holes made in the wall, to fire through with muskets.

Lunettes, are works made on both sides of a ravelin ; one of their faces is perpendicular to half or two thirds of the faces of the ravelin, and the other nearly so to those of the bastions.

Lunettes, are also works made beyond the second ditch, opposite to the places of arms ; they differ from the ravelins only in their situation.

M.

Mantlet, is a kind of moving parapet made of strong planks, about 4 feet long and 3 high, mounted upon two wheels, with a long pole fixed to it ; they serve to cover the sappers in the front against musket-shot.

Mine, is a kind of lodgment made under ground to place powder in it, which is set on fire, in order to blow up the works above it ; the difference between mines and countermines is, that the first are made by the besiegers, and the latter by the besieged.

Osta-

O.

Octagon, is an eight-sided figure of fortification.

Ondecagon, an eleven-sided one.

Orillon, is a part of the bastion near the shoulder, which serves to cover the retired flank from being seen obliquely.

Orgues, many harquebusses linked together or divers musket-barrels laid in a row, so that they may be discharged either all at once or separately; also long and thick pieces of wood with iron plates at the end, hung over a gate, to stop it up instead of a port-cullice.

P.

Palisades, are a kind of stakes made of strong split wood of about 9 feet long, fixed 3 feet deep in the ground in rows about 6 inches asunder; they are placed in the covert-way at 3 feet from, and parallel to the parapet or ridge of the glacis, to secure it from being surprised.

Parapet, is a part of the rampart of a work, of 18 or 20 feet broad, and raised 6 or 7 feet above the rest of the rampart: it serves to cover the troops, placed there to defend the work, against the fire of the enemy.

Parallels,

Parallels, or places of arms, are deep trenches 15 or 18 feet wide, joining the several attacks together; they serve to place the guard of the trenches in, to be at hand to support the workmen when attacked. There are generally three in an attack; the first is about 300 toises from the covert-way the second 190, and the third near or on the glacis; they were first invented or used by M. *Vauban*.

Petard, is a kind of a brass pot fixed upon a strong square plank, which has an iron hook to fix it against a gate or palisades; this pot is filled with powder, which when fired, breaks every thing about it, and thereby makes an opening for an enemy to enter the place.

Port-cullice, is a falling gate or door like a harrow, hung over the gates of fortified places, and let down to keep out the enemy.

Place, is commonly used in fortification instead of a fortified town.

Place of arms, of the covert-way, is a part of it, opposite to the re-entering angle of the counterscarp, projecting outwards in an angle.

Places of arms, in an attack; see *Parallels*.

Plat-

Plat-form, is a floor made of strong planks, laid upon joists, on a battery, to place the guns or mortars upon, in order to prevent the wheels or mortar-bed from sinking in the ground.

R.

Rampart, is an elevation of earth raised along the faces of any work, of 10 or 15 feet high, to cover the inner part of that work against the fire of an enemy.

Rams-horns, are a kind of low work made in the ditch of a circular arc; they were invented by M. *Belidor*, and serve instead of *tenailles*.

Re-entering angle, is that which turns its point towards the center of the place.

Ravelin. See *Demi-lune*.

Redans. See *Line of circumvallation*.

Redoubt, is a kind of work placed beyond the glacis, of various forms.

Redoubt, is also the name of a small work made in a ravelin, of the same form.

Redoubt, is likewise a square work without any bastions, placed at some distance from a fortification, to guard a pass, or to prevent an enemy from approaching that way.

Revete-

Revetement, is a strong wall built on the outside of the rampart and parapet, to support the earth, and prevent its rolling into the ditch.

Ricochet, when guns are loaded with small charges, and are elevated from 10 to 12 degrees, so as to fire over the parapet, and the shot rolls along the opposite rampart, it is called ricochet firing ; and the batteries are likewise called ricochet batteries.

S.

Sally, is when a party of a garrison goes out privately, and falls suddenly on the besiegers in their trenches, endeavouring to drive them out and destroy their works.

Saliant angle, is that whose point turns from the center of the place.

Second ditch, is that which is made on the outside of the glacis, when the ground is low, and water to be had.

Second covert-way, is that which is made beyond the second ditch.

Sap, is a trench or an approach made under cover of 10 or 12 feet broad, when the besiegers come near the place, and their fire grows so dangerous, as not to be approached uncovered.

Sau-

Saucisson, is a long pipe or bag, made of cloth or leather, of about an inch and a half diameter, filled with powder, going from the chamber of a mine to the entrance of the gallery ; it serves to give fire to the mine.

Saucisson, is likewise a fascine much longer than the common ones ; they serve to raise batteries, and to repair breaches.

Siege, is when an army approaches a fortified place, and surrounds it on all sides, endeavouring to oblige the garrison to surrender, either by destroying the works of the fortification, or whose which defend them.

T.

Talud, or slope, is made to the works of a fortification, both on the outside and inside, to prevent the earth from rolling down.

Traverse, is a parapet made cross the covert-way, opposite to the salient angles of the works, and near the places of arms, to prevent enfilades ; they are 18 feet thick, and as high as the ridge of the glacis. There are also traverses made in the caponiers, but then they are called *tambours*.

Traverses, are likewise made within other works, when there are any hills or rising grounds, which may see the inside of these works.

Tenailles,

Tenailles, are low works made in the ditch before the curtains ; there are three forts, *viz.* the first are the faces of the bastions produced, till they meet, but much lower ; the second have faces, flanks, and a curtain ; and the third, have only faces and flanks.

Tenaillons, are works made on each side of the ravelin, much like the lunettes ; they differ, in that one of the faces of a tenailon is in the direction of the face of the ravelin ; whereas that of the lunette is perpendicular to it.

Tower bastions, small towers made in the form of bastions by M. *Vauban*, in his second and third method ; with rooms or cellars underneath, to place men and guns in them.

The E N D.



